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NAVIGATING ENERGY-SAVING RETROFIT FINANCING: A PATHWAY THROUGH GAME THEORY AND COLLABORATIVE STRATEGIES

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Abstract

This paper explores the intricate dynamics of energy-saving retrofit financing, specifically focusing on the interplay between building owner-occupants and retrofitting providers. This arrangement establishes a symbiotic relationship, where building owners stand to gain from reduced utility expenses. In return, retrofitting providers recoup investments through a portion of cost savings resulting from energy-efficient enhancements. The study hones in on LED lamps as an energy efficiency product, outlining their benefits, shorter payback periods, and susceptibility to variations in operating hours and power costs. Addressing the challenge of split incentives – where retrofitting providers seek quick returns while owners' gains accrue gradually – the study advocates the application of game theory. This theoretical framework, modeling strategic interactions among rational agents, aids in resolving misaligned incentives between retrofit providers and building owners. The goal is to design contracts that encourage desired behavior, maximizing outcomes for both parties. The principle is to identify Nash equilibria where mutual benefits are maximized, reconciling providers' preference for short-term contracts with owners' interest in long-term schemes. Empirical evidence underscores the superiority of equitable partnerships over purely profit-driven approaches. To this end, the paper calls for co-creation of participatory ecosystems aligned with these principles. While game theory furnishes tools to analyze incentive conflicts and model solutions, the key lies in participatory processes engaging stakeholders to jointly develop partnerships, leveraging the insights from game theory and behavioral science. This amalgamation holds promise for achieving equitable retrofit financing, ultimately contributing to enhanced energy efficiency and reduced carbon emissions in the built environment.

Keywords: Game Theory, Retrofit Project, ESA & ESPC, Profit-loss Incentive Split.

Abbreviation:

ESPC: Energy Service Performance Contract

ESA: Energy Saving Agreement

LCCA: Life Cycle Cost Analysis

1. INTRODUCTION

This paper explores energy-saving retrofit financing, focusing on the dynamics between the building owner and the retrofitting provider (Ismiriati Nasip and Sudarmaji 2018 ;Liang, Peng, and Shen 2016). The financial contract addresses retrofitting buildings for improved energy efficiency and cost reduction. It emphasizes a mutually beneficial arrangement where the owner gains from reduced costs and increased property value while the provider recoups their investment through shared cost savings. The key is optimizing early utility cost reductions,

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translating energy savings into returns (Sudarmaji et al. 2021). Applicable across sectors, this model draws on principles of fairness and equitable behavior. A retrofit replaces outdated equipment with newer technology and adds new infrastructure, requiring upfront investment. The retrofit's value depends on the investment amount, energy costs, and operating hours, all affecting the payback time. As energy efficiency product prices decline but electricity costs rise (Ministry of Energy & Mineral Resources of the Republic of Indonesia 2018), retrofit financing is estimated to grow. Success depends on facilities operating over 8 hours daily. This paper investigates retrofit financing for LED lighting. LEDs use far less energy than traditional bulbs and last longer (Bennich 2015; Borg 2015), providing a short payback period. Increased operating hours or higher energy costs per watt impact the payback time.

Financing energy efficiency retrofits involves complex incentives between providers who undertake upgrades and occupants who realize long-term gains. Split incentives persist as providers want rapid returns while occupants' benefits accumulate slowly (Sudarmaji 2017). Novel financing frameworks to foster collaboration are needed. Game theory provides models to analyze strategic interactions between rational participants like retrofit agents and building owners (Liang, Peng, and Shen 2016). Since direct contracts optimizing both parties are difficult, side-contracts based on observable signals (energy savings) can be structured. Game theory offers ways to design contracts inducing desired behaviors from agents to maximize outcomes for principals. The key is identifying Nash equilibria where mutual gains are maximized (R. Cobb, Basuchoudhary, and Hartman 2013). For instance, providers prefer short-term ESPC contracts while occupants benefit more from long-term ESA schemes. Game theory suggests optimizing randomization between ESPC and ESA based on best response functions. This identifies a "mixed strategy" Nash equilibrium where incentives overlap, guiding negotiations. Beyond payoff matrices, behavioral game theory explores factors like social preferences, reciprocity, reputation, and trust to explain real-world behavior, rarely conforming to pure self-interest. Prospect theory shows losses loom larger than gains, impacting partnerships. Framing retrofits as gains or losses elicits different reactions. Profit-sharing may worsen divisions rather than align interests. Reciprocity and inequality aversion better explain social motivations underlying cooperation.

Empirical evidence shows equitable partnerships outperform profit-seeking. Minnesota's utility retrofit program recommends enhanced utility coordination, continued innovation, and attention to harder-to-reach sectors like low-income households and small businesses in order to achieve the technical potential identified. It also recommends greater policy clarity on issues like operational savings and incentives (Partridge 2020). The study estimates that energy efficiency programs funded by Minnesota's electric and natural gas utilities have the potential to cost-effectively reduce forecasted energy usage by 14% (electric) and 11% (gas) by 2029. In Germany, The study analyzes drivers and barriers for energy efficiency retrofits by German municipalities, using LED street lighting upgrades as a case example (Polzin, Nolden, and von Flotow 2018). Surveyed municipalities expected high energy savings potential from retrofits (over 50% savings for some), but cited barriers like budget constraints, lack of staff capacity, and long payback periods. The findings imply transparency, knowledge diffusion, skills development, and new business models could help transform retrofits into a distinct market

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and accelerate cities' infrastructure modernization. Therefore, Overcoming institutional barriers like contracts, public acceptance and showing collaborative frameworks outdo unilateral action was also found to be important.

Profit-sharing works only when structured as fair partnerships, not transactions. This study integrates game theory with behavioral science and partnership principles (Cartwright 2021). The hypothesis is that applying game theory can identify mutually beneficial outcomes reconciling conflicting provider and owner interests, by designing contracts inducing desirable behaviors and aligning incentives. The method combines theoretical analysis, empirical evidence, and participatory processes. Game theory provides useful tools to model solutions but real solutions come from understanding motivations and co-designing collaborative institutions based on reciprocity, transparency and shared purpose. Hence, beyond models, participatory processes engaging stakeholders to co-construct partnerships are key. Blending principles, motivations, and co-creation holds promise for equitable retrofit financing. Expected results encompass contract structures and strategies addressing split incentives and fostering collaboration. By leveraging game theory and behavioral science, this study aims to enable equitable retrofit financing and enhance energy efficiency.

2. LITERATURE REVIEW

The decision to use retrofit finance is viewed as a trade-off between rules and discretion on the owner-occupant side. In the case of a collapse, the provider would regain possession of the underlying asset and may decide to liquidate the assets. Since the assets cannot be redeployed, the retrofit provider will figure things out at a "High" cost for financing energy efficiency solutions (Qian, Chan, and Choy 2013). Since the assets are highly specific (i.e., non-re-deployable), interest and principal will be paid on schedule if the project is successful. Moreover, it is challenging for the retrofit provider to liquidate assets to recover their investments if the project fails. Financing the Retrofit to energy efficiency using the Profit-loss contract is a high-cost governance arrangement. These non-deployable assets carry a high level of risk, and the high liquidity needed to finance them would cause the company to run out of cash (Polzin, von Flotow, and Nolden 2016).

2.1 Retrofit-Financial in Game Theory Strategy

The key to business success in retrofitting is whether the provider is playing the fair game properly. Understanding the basic tenets of economics is aided by game theory. The paper of why owner-occupied make their choices is at the heart of economics, a specific field of the paper. The game theory was developed as a subset of economics when comprehending choices that owner-occupied's decision would affect the provider's decision. It involves examining choices that will affect both parties or what authors may refer to as "strategies." The fundamental idea underpinning game theory is that both parties can determine the best course of action in advance. To discover answers, it uses the Game theory Metaphorical Approach as a tool(He, Yue, and Wang 2016; Liang, Peng, and Shen 2016). Game theory is a technique used in the business world to examine the advantages and disadvantages of various business actions. In game theory, a strategy is pure if each step identifies a specific action. A strategy is

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considered mixed if at least one of the moves is subject to randomization. The randomization consists of a collection of predefined probabilities, where their total is 1.

As the opponent in the retrofit project, the game theory asks the company to estimate the worth of various choices. Authors must make certain assumptions about what provider desire (or value) and owner-occupant want for this paper (or values). Hence in this paper, authors have assumed that both provider and owner-occupant want to win a significant portion of saving incentives. This assumption that the provider and owner-occupant want to win the significant saving incentives is fundamental to game theory analysis. It is calling as "rational behavior" (Heukelom 2015). Hence, authors assumed that each party's goal is to earn as many points as possible or maximize their payoff; in economics, this payoff is often called utility. In the Game theory, authors considered that all players are rational agents, and each player knows all the other players are rational agents. Furthermore, both players make the choice that maximizes their payoff, given what other opponents do. Both parties should seek a "Nash-Equilibrium" (Liang, Peng, and Shen 2016).

This paper suggests a framework for making decisions that: (1) calculates the economic benefits of retrofit financing in terms of life-cycle cost for a specific energy efficiency lamp during its service life; (2) determines the best retrofitting budget that minimizes the total cost of the energy efficiency lamp during its service life; and (3) chooses the best energy retrofitting strategy (using game theory as a strategy) to maximize the return on investment. One method for comparing the total cost of ownership of mutually incompatible options is life cycle cost (LCC). LCC may be used as an economic strategy for assessing investment costs, including all expenses related to purchasing, using, and disposing of the asset (Petrillo et al. 2016). It is the entire discounted cost of purchasing, using, maintaining, and then selling an asset over a certain amount of time (Brown et al., 2013). In other words, LCC is a crucial tool for comparing the cost of ownership of mutually incompatible options. Realistic assumptions may be found by researching the performance of comparable assets over time, talking to manufacturers, suppliers, and contractors, doing literature studies and applying typical support and maintenance expenditures (Hong, Kim, and Kwak 2012).

The authors analyze the "investment cost" of energy efficiency investments compared to other investments using the LCC approach. The savings from energy efficiency are related to the costs of producing power over time. A summary of the advantages of energy efficiency savings that outweigh the initial investment expenses is given. On several occasions, the retrofit provider compares energy efficiency expenditures against other prospects for making investment returns. There are two methods to accomplish this. A yearly return on retrofit investment is the first. The second step is a risk analysis of a specific retrofit investment opportunity. Meanwhile, the energy-efficient bulb's duration (useful life) connected to the LCCA must be thoroughly documented and historically correct. Since nominal discount rates incorporate inflation, the discounted rate should also be applied. Therefore, the same discount rate must be used when comparing options over a particular period. Furthermore, there are several discount rates, which are likely to alter over time. Cost should be represented in constant IDR Rupiah when present value (PV) calculations are performed using the actual

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discount rate. LCC estimates should consider taxes and depreciation allowances. The straight-line technique of depreciation is often used. The difference in project finance methods between one alternative is called the value impact. For instance, ESPC financing has a lower return on investment than ESA financing. When creating a capital budget, the highest NPV projects consume all of the fixed investment cash available to the company (Brown et al., 2013; Kneifel and Webb, 2020). NPV is an investment's future cash flow (CF) value less the original investment. The cash flows in this paper are positive (inflows). It is best to choose the most prominent option with the greatest NPV.

2.2 Split Incentive Problems as a Principal-Agent Problem

The main point of contention between the provider and retrofit beneficiaries, in this case, is owner-occupant is the revenue-sharing or split incentive problem. The provider purchases and supplies all energy-efficient machinery under the terms of Profit-loss contract. Since providers have to pay for the up-front investment, they are incentivized to provide these at the lowest cost (rather than the maximum efficiency). However, there is little control over how to increase energy efficiency; in contrast, owner-occupants pay energy or utility costs and have strong incentives to do so. The life cycle of energy-efficient equipment determines how the proportion of incentives is distributed. If owner-occupants do not pay part of the provider's incentives, high initial capital cost expenditures are hazardous. Revenue-sharing issues are caused by temporal (temporary) incentives in energy-saving performance contract (ESPC) programs. The provider does not know how long they will get incentives since they depend on talks. The incentive must cover the total initial investment price for the energy-efficient equipment.

Therefore, the split incentive issue concerns the proper incentives division between the owner-occupant and retrofit provider. Two objectives are pursued in this study. The authors provide a general overview of the split incentive dilemma and its unique challenges. Split incentives are "a situation in which the flow of investments and benefits are not correctly rationed among the participants to a transaction. In rational choice economics, the split incentive dilemma is generally a well-known principal-agent issue (Ürge-Vorsatz et al. 2009). Any circumstance in which a principal pays an agent for an item or service is an agency dilemma. According to the notion, principals often have different objectives and knowledge than agents who provide them with products or services. Differences in both abound in the divided incentive dilemma. As a result, the principal-agent theory is a valuable tool for analyzing issues with the split incentive, especially those related to the incentive system for utility providers, landlords, and renters. Contracts that match the incentives of the two actors are the leading solutions to principal-agent difficulties, below the mechanism of game theory under the Profit-loss contract under ESA and ESPC arrangement (Figure 1). The ESA scheme incentives and the ESPC scheme incentives are the two forms of split incentive problems. The most well-known is the divided incentive issues between the owner-occupant and the retrofit provider. A retrofit provider (agent) purchases and provides all the parts for possibly energy-efficient lighting under the ESA plan. Since they do not have to pay the energy or utility bills, they are incentivized to provide these at the lowest cost (rather than the maximum efficiency). Another option is for the owner-occupant (or principal) to foot the cost for energy use, with solid incentives but no control over

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the methods to do so. The percentage rewards are distributed throughout the lamp's life (5 years). Suppose an owner-occupant fails to pay the provider's half of the energy incentives. In that case, the significant upfront capital cost investment is highly hazardous. The ESPC method in the temporal split incentive is the second kind of split incentive issue. Since the incentives must be granted based on talks, the agent is unsure how long they will get them in this circumstance. The incentives must cover the total cost of the equipment's overall investment in energy efficiency. Table 2 below showed that the energy-saving initiatives must be divided between the provider and the owner-occupant.

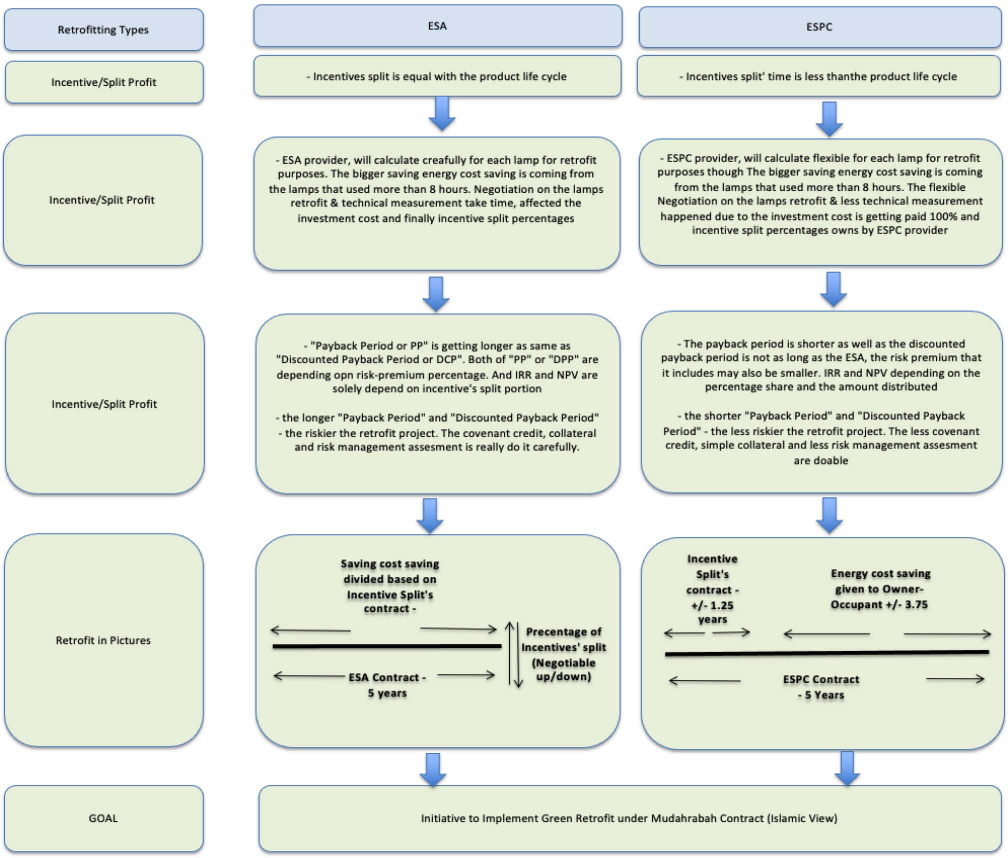

Figure 1: Mechanism Game Theory Under ESA/ESPC

Modified: Xin Liang et al. 2016

Table 2: Payoff Matrix of Strategy – Owner-Occupant and Retrofit Provider

Split Incentives Matrix		Retrofit Owner-Occupant	
		ESA	ESPC
Retrofit Provider	ESA	Both Owner & Provider considered Retrofit Incentives as "HIgh."	Provider considered Retrofit as "High" & owner as "Low Incentives."
	ESPC	Provider considered Retrofit as "Low Incentives" & Owner as "High."	Both Owner & Provider considered Retrofit Incentives as "Low Incentives."

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According to agency theory, the principal-agent dilemma is the split incentive problem. Risk, uncertainty, and information asymmetry are settings for this idea. The main concerns are the fees incurred by the principal while working with an agent and the separation of control that happens when a principal engages an agent (agency costs). These agency costs may result from creating financial or ethical rewards to influence the agent's behavior. In a principal-agent relationship, one entity formally designates another to act on its behalf. While there is a principle-agent connection, the agent represents the principal and should not have competing interests when performing the act. In a contract, the formal conditions of a particular principal-agent relationship are often laid forth. A similar issue that may be characterized as a principal agent in energy efficiency saving contracts was discovered by Jaffe, Newell, and Stavins (2004). Since the owner-occupant-retrofit provider connection in this paper is one of a kind and a particular circumstance, it might be challenging to identify the primary and the agent in this relationship. This connection has less information asymmetry, and both parties know the advantages of cost-energy efficiency reduction.

3. RESEARCH METHOD

In this paper, the authors identified that the problem, in reality, is mapped to a conceptual framework to guide the identification and subsequent weighting of the retrofit factors related to the misunderstanding of requirements (Latham 2016). The owner-occupant significantly impacts retrofit choices, especially at the beginning, at the primary intention or setup phase (Liang, Peng, and Shen 2016). The owner participates in this step, offering early retrofit designs and exchanging views on refit. The owner and the provider may choose whether to go on with a retrofit project's energy assessment, design, and implementation phases. Owner-occupant may reduce their energy use by becoming energy-conservative (Ismiriai Nasip and Sudarmaji 2018; Ismiriati Nasip and Sudarmaji 2018; Sudarmaji et al. 2021; Sudarmaji, Ambarwati, and Munira 2022). Owner-occupant is thus a crucial partner in retrofit initiatives. If an agreement with the provider cannot be reached, the project retrofit may be stopped. It is necessity for a shared understanding of a retrofit between owner-occupant and provider as the essential phase of a retrofit and said that the information sharing and consensus must match. Therefore, the relationships between the owner-occupant and the provider are crucial. The proposition is outlined below.

Proposition 1: The ESPC and ESA contracts under Profit-loss finance in Indonesia are highly likely to be executed,

Proposition 2: A "mix strategy equilibrium and response function" is employed to examine the retrofit business choices to address the split incentive difficulties.

2.3 Game Theory as Metaphorical Approach

The authors used a concept of equilibrium known as Nash equilibrium, formulated by John Nash in the 1950s in the strategic context of game theory (Holmstrom and Milgrom 2012). A Nash equilibrium is a situation in which the equilibrium tactics of the other players determine each player's optimal course of action. In this paper, the authors look at mixed strategies, which

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let the owner-occupant and the retrofit supplier choose randomly between two potential contracts. Both have to select the ESA agreement or the ESPC agreement. The reward to the owner-occupant in the principal-agent model relies on a move made by the retrofit provider. Although the owner-occupant cannot agree to pay the provider directly for the activity, they may do so in exchange for some visible signal that is associated with the action. The provider is the innovator and selects an incentive plan for compensating the owner-occupant based on the signal detected. The owner-occupant then chooses the best course of action given the incentives. Based on the anticipated money, the estimated subjective cost of doing the activity decides whether to accept the provider's offer. The provider observes the signal associated with the action, pays the owner-occupant under the incentive structure, and gets a reward based on the signal. Once the owner-occupant chooses an action, the provider maximizes his payoff after accepting it. Although the owner-occupant's activity is not a precommitment by the principle, the incentive plan is.

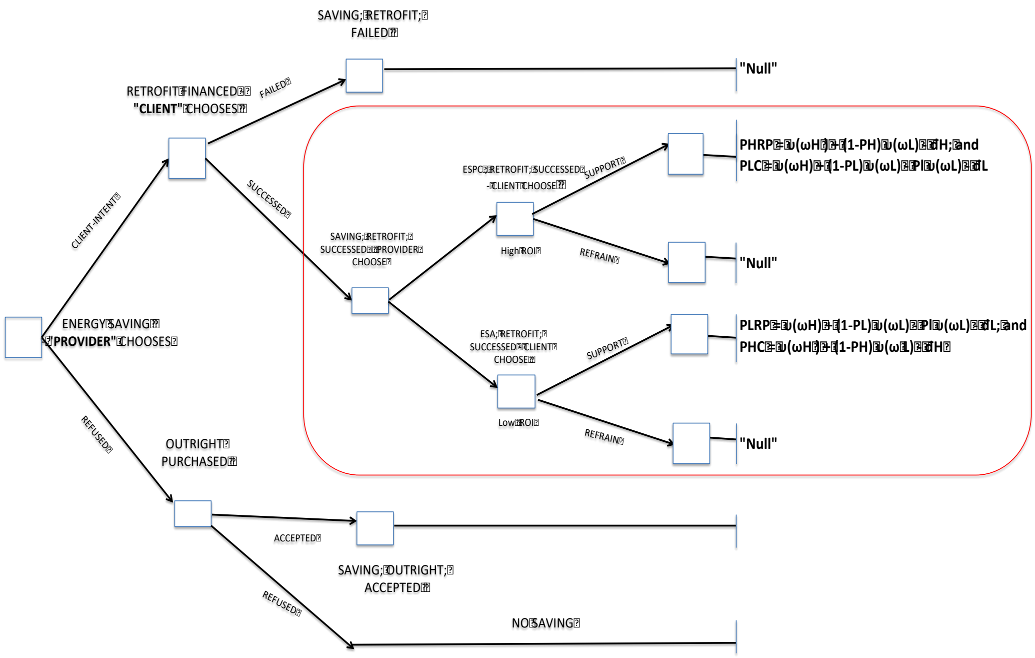

Figure 2: the form of the game tree equation.

The owner-occupant hires the provider to do a job. There are two possible levels of incentives for the owner-occupant, high (πH) and low ($\pi L < \pi H$). The provider can affect the probability of high incentives by choosing to make the business relationship with either high or low effort. With high effort, the probability of high incentives is PH. With low effort, the probability of low incentives is PL , where $0 < PL < PH < 1$. If the owner-occupant could see the provider's choice of effort, he could write a contract for high effort, but he cannot. He can only induce the provider to work hard is to offering the proper incentive contract. Then he pays the payoff ωH if incentives are high and $\omega L < \omega H$ if incentives are low. The details payoff $\upsilon(\omega)$, can be derived from Bengt Holmstrom and Paul Milgrom's four principles in the linear model and being

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popularly used by Prendergast (1999). How should the owner-occupant choose ωL and ωH to maximize expected incentives? The game tree for this situation is deployed (Figure 2), where we assume the utility of the payoff is $\upsilon(\omega)$, and the cost of high effort to the provider is **đ**H. The cost of low effort is **đ**L < **đ**H. By working hard, the provider faces a lottery with payoffs $\upsilon(\omega H)$ – **đ**H; $\upsilon(\omega L)$ – **đ**H; $\upsilon(\omega L)$ - **đ**H and probability PH, 1 – PH, with an expected value of **đ**H. The expected value of which is

“$PH_{RP} = \upsilon(\omega H) + (1-PH)\ \upsilon(\omega L) - \text{đ}H$” : (payoff High incentive of Retrofit Provider), and

“$PL_{C} = \upsilon(\omega H) + (1-PL)\ \upsilon(\omega L) - Pl\ \upsilon(\omega L) - \text{đ}L$” : (payoff Low incentive of Owner-occupant).

With low effort, the corresponding expression is

“$PL_{RP} = \upsilon(\omega H) + (1-PL)\ \upsilon(\omega L) - Pl\ \upsilon(\omega L) - \text{đ}L$” : (payoff Low incentive of Retrofit Provider), and

“$PH_{C} = \upsilon(\omega H) + (1-PH)\ \upsilon(\omega L) - \text{đ}H$” : (payoff High incentive of Owner-occupant).

The authors can depict the extensive form game based on the equation above.

“PLRP = υ(ωH) + (1-PL) υ(ωL) - Pl υ(ωL) - đL” : (payoff Low incentive of Retrofit Provider), and

“PHC = υ(ωH) + (1-PH) υ(ω L) - đH” : (payoff High incentive of Owner-occupant).

A set of possible payoffs from the above set of assumptions can be seen in this table. 3 below. The below table exhibits the defining feature of coordination games in retrofit financing: payoffs are higher when both players coordinate their actions.

Table 3: The possible payoff as defining feature of coordination

Split Incentives Matrix		Retrofit Owner-Occupant			
		ESPC		ESA	
Retrofit Provider	ESPC	$PH_{RP} = \upsilon(\omega H) + (1-PH)\ \upsilon(\omega L) - \text{đ}H$ NASH EQULIBRIUM	PLC = $\upsilon(\omega H) + (1-PL)\ \upsilon(\omega L) - Pl\ \upsilon(\omega L) - \text{đ}L$	0	0
	ESA	0	0	NASH EQULIBRIUM $PL_{RP} = \upsilon(\omega H) + (1-PL)\ \upsilon(\omega L) - Pl\ \upsilon(\omega L) - \text{đ}L$	$P_{HC} = \upsilon(\omega H) + (1-PH)\ \upsilon(\omega L) - \text{đ}H$

INCENTIVES HIGH IS DOMINANTS PROVIDER CHOICES

INCENTIVES HIGH IS DOMINANTS OWNER CHOICES

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4. RESEARCH RESULT

This phase reviews the context of finding "ESPC and ESA under Profit-loss Financing" and its relationship to the provider's financing strategy, financing models, and strategies for correctly playing the suitable game. In order to evaluate the entire cost, value, risk, and liquidity effect on investment prospects with its resources, the ESPC and ESA provider used LCCA Method analytical tools. Energy efficiency initiatives must be judged equally with other projects to compete effectively with other enterprises. Hence the fundamental analytical tool and basic LCC measurements utilized in this retrofit project (Cabeza et al. 2014; Kneifel and Webb 2020). The provider uses financial analysis to determine if an investment meets the necessary degree of profitability while meeting the financial owner-occupant investment and liquidity demands.The original cost of the LED lamp investment, maintenance costs, special repair costs, operating costs, replacement costs, energy costs, administrative costs, taxation costs, renovation costs, and disposal costs are the primary cost components of this LED retrofit throughout its service life. One of the critical components of any LCC analysis that relies on the inflation rate is the interest rate. Throughout the project's service life, this rate could not remain constant. An acceptable range is between 2 and 3 percentage points above inflation. A LED should last for a maximum of five years. For the formulation of the LCC equation, the following cost factors are chosen: Costs associated with the initial investment (IC), energy consumption (EC), and maintenance and replacement (MR). So, the following formula may be used to compute the change in LCC of a structure as a result of energy retrofits:

$$LCC = IC + PVEC + PVMR$$

The paper used the same procedures and principles as EPA-Energy Start (United States Environmental Protection 2008) to evaluate the project's viability. The processes consist of determining if the ESPC and ESA contracts are feasible by doing the LCC analysis. For each option contract, determine the degree of profit from each option by calculating the IRR. While accounting for the needed rate of return (hurdle rate), authors were Utilizing the NPV to evaluate and order choices and then determine which option would optimize energy efficiency. Internal rate of return (IRR) projections that exceed the necessary investment are often used to gauge profitability (hurdle rate). Before determining the return rate, the owner-occupant's cash flow and financial liquidity are assessed (payback). The hurdle rate is the standard to accept or reject an investment's capacity to profit. The project is a successful investment if the IRR exceeds the needed rate of return. The required interest rate is the marginal cost of capital modified for the project's level of risk. The degree of profit needed increases as risk and capital costs rise. EPA Energy Star advises utilizing a 20% needed return rate for energy efficiency investments (Azar and Menassa, 2014). The viability of this investigation is evaluated in the first phase, the sensitivity analysis (Ramanathan and Ganesh 1995). The sensitivity analysis made it possible to examine how an energy efficiency saving model's output uncertainty might be divided among multiple sources. It may be used to decide which operating hours and electricity pricing inputs would increase energy efficiency the best. The most efficient technique to get a better understanding is using importance measures for each unknown input variable on the fluctuation of electricity tariffs and operating hours.The next step: is the

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scenario analysis. Retrofit's key assumptions; following the first step of sensitivity analysis, the authors had to make many assumptions to estimate the energy-saving split incentive problem, which possibly appeared on both provider and owner-occupant energy-saving potential. Most of these assumptions concerned the risk-adjusted discounted rate of upfront investment and split-saving incentives into various levels of scenario type. This scenario analysis investigates the effect of changing the values by changing the key assumptions. The values can be increased or decreased based on reasonable assumptions, and the corresponding changes in energy savings were noted. The scenario analysis and results are shown.

Table 4: Scenario Analysis for ESA Scheme on Incentives Split Problem

ESA SPLIT INCENTIVES

Split Incentives	Suku Bunga Internal %	8.00%	10.00%	12.00%	14.00%	16.00%	18.00%	20.00%
70% (5Yrs)	Net present value (IDR)	82,291	67,910	54,906	43,124	32,430	22,707	13,851
	Internal rate of return (%)	138.50%	134.16%	129.98%	125.94%	122.05%	118.28%	114.65%
	Discounted payback period - Year(s)	**0.5184**	**0.4824**	**0.5229**	**0.5659**	**0.6116**	**0.6601**	**0.7115**
60% (5yrs)	Net present value (IDR)	30,208	43,923	32,776	22,677	13,511	05,177	97,587
	Internal rate of return (%)	95.21%	113.03%	109.23%	105.56%	102.02%	98.59%	95.28%
	Discounted payback period - Year(s)	**0.6221**	**0.5628**	**0.6100**	**0.6603**	**0.7136**	**0.7701**	**0.8300**
50% (5Yrs)	Net present value (IDR)	30,208	19,936	10,647	02,231	94,593	87,648	81,322
	Internal rate of return (%)	95.21%	91.66%	88.24%	84.94%	81.75%	78.67%	75.69%
	Discounted payback period - Year(s)	**0.6221**	**0.6754**	**0.7321**	**0.7923**	**0.8563**	**0.9242**	**0.9960**
40% (5Yrs)	Net present value (IDR)	04,166	95,949	88,518	81,785	75,674	70,118	65,058
	Internal rate of return (%)	73.02%	69.87%	66.84%	63.91%	61.08%	58.35%	55.71%
	Discounted payback period - Year(s)	**0.7776**	**0.8442**	**0.9151**	**0.9904**	**1.0704**	**1.1552**	**1.2450**
30% (5Yrs)	Net present value (IDR)	78,125	71,962	66,388	61,339	56,756	52,589	48,793
	Internal rate of return (%)	50.03%	47.30%	44.67%	42.13%	39.68%	37.32%	35.03%
	Discounted payback period - Year(s)	**1.0368**	**1.1256**	**1.2201**	**1.3205**	**1.4272**	**1.5403**	**1.6601**
20% (5yrs)	Net present value (IDR)	52,083	47,974	44,259	40,892	37,837	35,059	32,529
	Internal rate of return (%)	25.43%	23.15%	20.95%	18.83%	16.78%	14.80%	12.89%
	Discounted payback period - Year(s)	**1.5552**	**1.6884**	**1.8301**	**1.9808**	**2.1408**	**2.3104**	**2.4901**

INCENTIVES HIGH IS DOMINANTS PROVIDER CHOICES

INCENTIVES HIGH FOR BOTH PROVIDER & CLIENTS (NASH EQULIBRIUM)

INCENTIVES HIGH IS DOMINANTS CLIENTS CHOICES

The scenario analysis results, in this case, provide fresh perspectives on the variables that affect the provider's choice to go through with the retrofit project for energy efficiency under the ESA or ESPC scheme. The range of values for the discounted payback time (years), IRR, and NPV across several scenarios is the most helpful information from the scenario analysis below in tables.4 and 5. This information gives a quick indication of how risky the investment is. According to this scenario analysis, the data may be used to identify the analytical inputs with the most significant impact on value. The LCC calculates the amount of energy saved for 1pc of LED bulb. In the case of ESA split incentives, where discounts range from 8% to 20%, the provider's top incentive options lay in the 50%–70% split scheme region. On the other hand, the 20%–50% split scheme region has the more substantial prevailing incentives for the owner-occupant. The region divided in half contains the overlapping, the potential for complex negotiations, and the Nash-equilibrium for both of them. Negotiations between the parties will center on the inferred discounted rate and how the saving incentive will be shared.

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Table 5: Scenario Analysis for ESPC Scheme on Incentives Split Problem

ESPC SPLIT INCENTIVES

Split Incentives	Suku Bunga Internal %	8.00%	10.00%	12.00%	14.00%	16.00%	18.00%	20.00%
1 year	Net present value (IDR)	89,333	86,236	83,250	80,368	77,586	74,898	72,300
	Internal rate of return (%)	110.29%	106.46%	102.78%	99.22%	95.79%	92.47%	89.26%
	Discounted payback period - Year(s)	**0.9067**	**0.9393**	**0.9730**	**1.0079**	**1.0440**	**1.0815**	**1.1203**
1.25 Years	Net present value (IDR)	209,762	205,245	200,913	196,756	192,764	188,928	185,238
	Internal rate of return (%)	131.33%	127.12%	123.07%	119.16%	115.38%	111.73%	108.20%
	Discounted payback period - Year(s)	**0.3862**	**0.3947**	**0.4032**	**0.4117**	**0.4202**	**0.4287**	**0.4373**
1.5 Years	Net present value (IDR)	249,191	243,253	237,576	232,144	226,942	221,957	217,175
	Internal rate of return (%)	149.33%	144.80%	140.43%	136.21%	132.14%	128.20%	124.40%
	Discounted payback period - Year(s)	**0.3251**	**0.3330**	**0.3409**	**0.3489**	**0.3569**	**0.3649**	**0.3730**
2 Years	Net present value (IDR)	328,049	319,269	310,902	302,920	295,298	288,016	281,050
	Internal rate of return (%)	179.86%	174.77%	169.87%	165.13%	160.56%	156.14%	151.88%
	Discounted payback period - Year(s)	**0.2469**	**0.2537**	**0.2605**	**0.2674**	**0.2743**	**0.2812**	**0.2882**
2.25 Years	Net present value (IDR)	364,558	353,822	343,637	333,962	324,762	316,006	307,665
	Internal rate of return (%)	184.34%	179.17%	174.19%	169.38%	164.73%	160.24%	155.91%
	Discounted payback period - Year(s)	**0.2222**	**0.2289**	**0.2357**	**0.2425**	**0.2494**	**0.2563**	**0.2633**
2.5 Years	Net present value (IDR)	401,066	388,375	376,371	365,004	354,226	343,997	334,279
	Internal rate of return (%)	188.58%	183.34%	178.28%	173.39%	168.68%	164.13%	159.73%
	Discounted payback period - Year(s)	**0.2020**	**0.2086**	**0.2152**	**0.2219**	**0.2287**	**0.2355**	**0.2423**

INCENTIVES HIGH IS DOMINANTS CLIENTS CHOICES (1 year)

INCENTIVES HIGH FOR BOTH PROVIDER & CLIENTS (NASH EQULIBRIUM) (1.25 Years)

INCENTIVES HIGH IS DOMINANTS PROVIDER CHOICES (1.5 Years – 2.5 Years)

Meanwhile, under the ESPC split incentive scenario, data from the LCC calculation for values of discounted payback period (years), IRR. NPV with discounted rates ranging from 8% to 20% revealed that the higher dominant incentives for the provider lie at one year to 1.25 years with total saving energy given to the provider and for the owner-occupant at 1.5 years to 2.5 years. The negotiation window and potential Nash-equilibrium time frame are 1.25 years. In addition to the ESA, one of the negotiating issues involving both parties under the ESPC will be the discounted rate. Tables 4 and 5 above show the results of the LCC Analysis for cash flow, NPV, payback time, and IRR. The profitability of this refit project exceeded the amount of investment necessary (hurdle rate). Owner-occupants cash flow and financial liquidity had internal rates of return (discounted payback) that ranged from 8% to 20%. The discounted rate utilized in this project is typically the sum of the interest rate on deposits plus the cost of carrying risk for risks assumed by the provider.

The project's rate of return over the payback period demonstrates that the risk is relatively modest. The NPV demonstrates that under the greater dominating incentives area, the overall net cash flow created by the ESA project and ESPC project throughout its five-year life is positive. The project is declared profitable since the IRR is higher than the hurdle rate, or needed interest rate, of 20%. **"Proposition 1: The ESPC and ESA contracts under Profit-loss in Indonesia is extremely viable to be executed by provider" is thus validated by the authors.** The discounted payback period (years), IRR, and NPV analysis where good shape under energy cost is continuing increase and scarce company to do the similar business, especially under stiff competition in LED market. In the contract context, the game theory is used as a tool to use to analyze the costs and benefits of certain business decisions. Under a mixed strategy, it applies some randomization to at least one of the moves. As authors

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mentioned earlier, the authors used game theory to understand decisions that the provider would affect the owner-occupant's decision as authors considered "strategies." The authors attempt to imitate the Nash equilibrium for the owner-occupant and the provider under "rational conduct." In order to examine this retrofit scenario, authors place themselves in the position of the "Provider" and attempt to forecast using game theory how to maximize best the divided incentive issues between them and the owner-occupant. The owner-occupant and the provider want to coordinate the installation of retrofit energy-efficiency equipment. The authors build a scenarios matrix based on the questions-ask above to anticipate a reward matrix and accessible options. Setting up a payout matrix might be complex since authors need to calculate with some degree of precision. Since the authors assume the role of a "provider" in these settings, authors conduct market research and provide acceptable comparative estimations of the payoffs a provider may experience in each scenario. In this paper, authors assumed that ten executives or managers and ten prospective owner-occupants would be surveyed to ascertain their chance of selecting "ESPC" rather than "ESA." To identify each possibility, they discuss the sensitivity analysis of the payback period paper for both the ESA and the ESPC. To accomplish this, the authors use questionnaire surveys with questions related to each situation.

Below are the question-asks illustrated: What kind of strategies to handle the owner-occupant and the problem issue between the provider and the owner-occupant? What kind of incentives are given by the provider to the owner-occupant? Do the provider and owner-occupant have any financial tools? How do they know the ESA or ESPC? If ESA is a long-term commitment with long-term split incentives payment from owner-occupant. Then ESPC is a short-term commitment with short-term payment; which contract item does the provider prefer, ESA or ESPC? What does the provider prefer in terms of ESPC-specific payback periods compared to ESA? If the owner-occupant chose ESPC over ESA, how much did the provider consider the payout between them? These questions were to validate the primary assumption of the paper, that provider's management thinks investment payback terms as a particular consideration are better or worse. In a survey, authors may ask to score each event on a scale of 0 to 10.

Table 6: the form of the payoff

Split Incentives Matrix		Retrofit Owner Occupant				
		ESPC		ESA		
Retrofit Provider	ESPC	NASH EQULIBRIUM 10	4	0	0	10q+0(1-q)
	ESA	0	0	NASH EQULIBRIUM 5	8	5(1-q)
			4p+0(1-p)		8(1-p)	

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Above is the summary of two different scenarios of the split incentives problem, namely ESA and ESPC, in table 6. The mixed strategy that needs to be applied to tackle the issue of split incentives will be drawn based on the classical theory issue in the game theory.

4.1 Game Theory Scenario Matrix

Based on the two different scenarios of split incentives in Table 6 above, both players have the dominant strategy (Nash equilibrium). Authors can use this information to calculate the best response functions for providers and owner-occupant. Figure 3 shows this game has precisely one mixed strategy equilibrium, which involves the provider choosing ESPC with a probability of 67% and the owner-occupant choosing ESA with a probability of 33%. This equilibrium does not just involve owner-occupant randomizing whether to choose ESA or ESPC or Provider randomizing whether to defend ESA or ESPC. The equilibrium requires the provider and owner-occupant to do these things with specific frequencies. All this graph tells us is that whenever a provider chooses ESPC less than 67% of the time (p), the owner-occupant should choose ESPC 33% of the time (q). Furthermore, whenever the provider chooses ESA more than 33% of the time (p), the owner-occupant should choose ESA 67% of the time (q).

Considering other players' tactics, the optimum response in game theory is the approach (or strategies) that result in the player's preferred outcome. The Nash equilibrium is the point at which each player in a game has chosen the best answer (or one of the best responses) to the other player's tactics. It is John Nash's best-known contribution (R. Cobb, Basuchoudhary, and Hartman 2013). The Nash equilibrium is fundamentally based on the idea of the best response (Chaigneau and Edmans 2013). According to the ESA and ESPC contracts, the retrofitting provider will optimize the payout, given the owner-occupant approach.

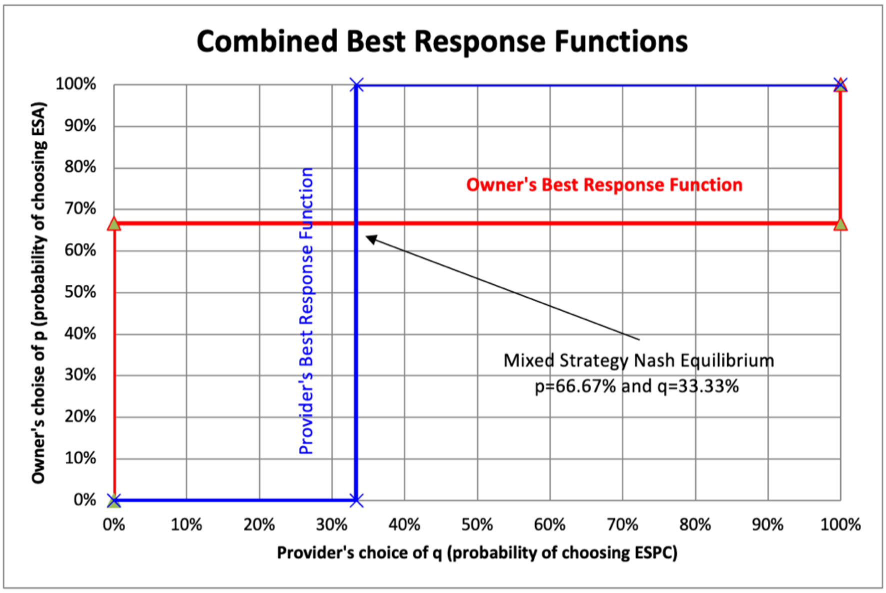

Figure 3: The Best Response Strategy

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The key lesson from the mixed approach is that it requires managers to think ahead and backward by forcing them to place themselves in the owner-occupant's position. It is because the retrofit provider is allocentrically focused on the client side. The provider must provide additional incentives for owner-occupants to maximize the value added to their retrofit project. Without needing the owner-occupant to fail or feel lost, the retrofit project may be successful. As a result, the management may benefit by creating a game suitable for the provider and altering the game. Instead of preserving the status quo, the provider may ultimately get higher compensation. As a result, the authors came to a conclusion and affirmation that **"Proposition 2: The strategy under game theory may use as a tool to tackle the split incentive problems".** The managers must adopt allocentric viewpoints to grasp the implications of their retrofit initiatives to comprehend the divided incentive concerns. Predicting the owner-actions occupants in response to the efforts taken is crucial.

5. CONCLUSION

Profit-sharing contracts have been integrated into retrofit financing, alongside the exploration of ESA and ESPC funding models, as detailed in this study. This interaction involves a contractual arrangement between the property owner and the retrofitting service provider, fostering a joint effort in executing environmentally-friendly retrofits with profit-sharing provisions. In this context, the retrofit provider assumes the role of a capital owner, undertaking the financing of all retrofitting endeavours as a complete investor. Simultaneously, the property owner is entrusted with the efficient management of the project, capitalizing on the investment by the partner. The distribution of profit-sharing ratios between the capital provider and the project manager is arrived at through collaborative negotiations.

This study used decision Trees and game theory practices to show the process of the retrofit deal. Hence it must pass through a series of tests, with failure at any point potentially translating into a complete loss of value. The outcome shows the probabilities of success at each phase associated with each step. There are several benefits to having a decision tree and game theory in this retrofit study: 1) Dynamic response to the outcome: by linking actions and choices to outcomes of uncertain events, 2) value of information, it provides a valuable perspective on the value of information in decision making, 3) management strategy, it provides a picture of the outcome, is instrumental in deciding what dominant choice or benefits of doing so—considering the value of information on the electricity bill, consumption hour, tariff, and split incentives problem, where the provider's best-case scenario unfolds.

Whether you are playing the fair game properly is the key to business success. Knowing the fundamental concept underlying the movements is aided by game theory. It provides empirical justifications for people's choices. The Game theory is used in this paper to comprehend how a provider's choice may impact an owner's choice. Occupant's analysis of provider actions that may affect owner-occupant decisions or calls for a "strategy" is included. The basic idea underlying game theory in this subject is that the provider can determine the best course of action before doing it. To discover answers, it uses mathematics as a tool. Game theory is employed in the Profit-loss setting to examine the costs and advantages of the funding options

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for retrofits. Because a provider's approach in this study applies some randomization to at least one of the movements, such as ESA or ESPC, it was classified as mixed. This study offers insights into the fusion of profit-sharing contracts, decision trees, and game theory within the domain of retrofit financing. The principles of profit-sharing, dynamic outcome assessment, and strategic alignment underscore the collaborative journey between capital providers and project managers. Anchored in fairness and strategic foresight, these methodologies converge to empower stakeholders in steering retrofit initiatives toward optimized, equitable, and mutually beneficial outcomes.

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