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APPLICATION OF GENERATIVE PRE-TRAINED TRANSFORMER AS AN EXPERT SYSTEM RECOMMENDING THE TYPE OF HEATING

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ABSTRACT

Purpose: *The aim of this article is to develop and verify an expert recommendation system based on ChatGPT (Generative Pre-Trained Transformer), which helps in selecting a heat source.*

Need for the study: *With the development of large language models, the capabilities of artificial intelligence to process, interpret and infer from data are growing. These features are used in complex decision-making problems. One of these problems is the selection of a heating system.*

Methodology: *The construction of the system included collecting data and preparing a domain knowledge base, followed by testing and fine-tuning. The verification of the developed system was carried out using case studies, including confirmation of the heat source selected by human experts or selection of a heating system. In addition, the performance and recommendations of the expert system were compared with the performance and recommendations of the original ChatGPT 4o.*

Findings: *The research results indicate that the expert system, unlike the original ChatGPT, provided more precise calculations and more detailed data. Moreover, in the case of incomplete data, the system asked for details, reducing the risk of incorrect recommendations.*

Practical Implications: *This type of ChatGPT-based expert recommendation system can effectively replace domain experts and positively influence the decisions made by individual stakeholders, businesses, and public institutions.*

Keywords: generative artificial intelligence, expert system, large language model, ChatGPT, heating systems, heat sources

Jel codes: C45; C69; C88; Q40

1. INTRODUCTION

In recent years, there has been a dynamic development of LLMs (Large Language Models). Models such as ChatGPT (Generative Pre-Trained Transformer) (Stribling et al., 2024), DeepSeek (Xie et al., 2025), Gemini (Hirosawa et al., 2024), Claude (Caruccio et al., 2024), LLaMA (Large Language Model Meta AI) (Chiu & Hung, 2025) and many others (Kunze et al., 2025) are finding more and more applications in which they replace humans. It is considered that ChatGPT is

currently the most popular LLM (Zhang et al., 2023). ChatGPT was trained on a large corpus of text data. It uses deep learning algorithms to analyse and interpret natural language and generate text-based responses (Ullah et al., 2024). Unlike classical artificial intelligence methods, which are designed to automate routine and repetitive tasks, ChatGPT can replace highly skilled workers (Dong et al., 2024). In particular, it can fill the gap between complex raw data and meaningful and human-readable observations by answering questions, summarizing and interpreting data, sometimes outperforming human experts (Zagar et al., 2025). The above-mentioned features of ChatGPT are the basis for its use as a domain expert in complex problems requiring data processing and interpretation, as well as reasoning. One of such problems, with a high degree of complexity, is the selection of a heating system for a single-family house. This is a key decision that affects the costs and comfort of living. In turn, the dynamic changes in the EU climate policy in recent years, including ETS (Emissions Trading System), ETS 2, European Green Deal, Fit for 55, etc. (Jorge-Vazquez et al., 2024), make the choice of a heat source a complex decision-making problem (Miranda-Quiñones et al., 2024). The large number of different heating systems available on the market further complicates this problem. Therefore, it is important to propose a useful tool that helps in choosing a heating system. This creates a research gap concerning whether a properly trained LLM like ChatGPT can be used as an expert system to support users in the selection of a heating system. This gap gives rise to research questions about how the model should be constructed and trained, and what kind of results can be expected.

The aim of the article is to develop and verify an expert recommendation system that helps in selecting a heat source. This system will be based on ChatGPT, thanks to which it will communicate with the user using natural language. The system will enable the selection of heating based on the user's individual preferences, housing conditions, infrastructure availability and economics of use.

2. CONSTRUCTION OF AN EXPERT SYSTEM BASED ON CHATGPT

The construction of an expert system for recommending heat sources for a single-family house based on the needs and capabilities of the user began with data collection. The fact that the system will be intended for users in Poland is of crucial importance for the selection of the scope and data sources for the system. Therefore, data on heating costs and available technologies were taken from Polish specialist websites: kb.pl (*Budowa, remont, wykończenie - KB.pl*, 2025), samurio.pl (Maron, 2023), extradom.pl (Kaliska-Borowicz, 2023), mgprojekt.com.pl (*Ogrzewanie domu*, 2025), www.portalsamorzadowy.pl (Krzemiński, 2023), businessinsider.com.pl (*Jak tanio ogrzać dom?*, 2024), rotal.pl (*Jakie ogrzewanie do starego domu wybrać?*, 2024), home.morele.net (Przyborowska, 2022), engocontrols.com (*Which home heating is the most economical*, 2023), murator-dom.pl (Kazimierowicz, 2025). Additionally, data published by the Industry Agreement for Energy Efficiency POBE (*Porozumienie Branżowe Na Rzecz Efektywności Energetycznej POBE*, 2022) were used. These data include a heating cost calculator (*Kalkulator POBE – Koszty Ogrzewania w Typowych Budynkach w I Kwartale 2025 r.*, 2025) and information on changes for the construction sector in the scope of the “Fit for 55” package (Wróbel, 2021) in relation to heat sources. The expert system also implemented knowledge related to the ‘My Heat’ (Narodowy Fundusz Ochrony Środowiska i Gospodarki Wodnej, 2025b) and ‘Clean Air’ (Narodowy Fundusz Ochrony Środowiska i Gospodarki Wodnej, 2025a) programs.

Data collected from various sources required cleaning and conversion to a uniform knowledge base format. The data processing process included the following elements:

- Removal of unnecessary information, graphics, metadata and advertisements.
- Normalization of values to the ISO 8601 format.
- Segregation of data into separate files containing individual heat sources.
- Removal of data redundancy.
- Merging data into a single knowledge base file.
- Formatting data for more efficient processing by LLM. Formatting included changing the case of letters, removing unnecessary characters, unifying separator characters and rebuilding tables.

Using the capabilities of LLM ChatGPT to work with PDF files, the collected data was transformed and merged into files in this format. The data were segregated, cleaned and reformatted. Incorrect data,

duplicates and unnecessary content were removed in this way. Despite the convenience of working with the PDF format, some content containing tables, charts and sheets may be incorrectly recognized by LLM. Therefore, this type of data was prepared in a structured CSV format. The collected and processed data were added to the LLM ChatGPT knowledge base and used in the expert recommendation system.

Based on the information contained on the previously mentioned subject-related websites (*Budowa, remont, wykończenie - KB.pl*, 2025; *Jak tanio ogrzać dom?*, 2024; *Jakie ogrzewanie do starego domu wybrać?*, 2024; *Kalkulator POBE – Koszty Ogrzewania w Typowych Budynkach w I Kwartale 2025 r.*, 2025; *Ogrzewanie domu*, 2025; *Porozumienie Branżowe Na Rzecz Efektywności Energetycznej POBE*, 2022; *Which home heating is the most economical*, 2023; Kaliska-Borowicz, 2023; Kazimierowicz, 2025; Krzemiński, 2023; Maron, 2023; Narodowy Fundusz Ochrony Środowiska i Gospodarki Wodnej, 2025a, 2025b; Przyborowska, 2022; Wróbel, 2021), the basic data needed to generate recommendations were defined:

- Technical data of the building.
- Preferred type of the heating system.
- Annual indicator of demand for usable energy (*Jak obliczyć zapotrzebowanie energetyczne domu lub mieszkania?*, 2024) or building insulation standard.
- Whether the building is new or modernized.
- Location (voivodeship or municipality) – potential subsidy programs.
- Infrastructure – availability of the media (access to gas or electricity), possibility of installing an LPG tank, heat pump, wood or pellet storage.
- Ecology – does it depend on low CO₂ emissions and renewable sources.
- Investment budget – approximate range of funds for investment.
- Operating budget – maximum heating cost per year.
- System operation – preferences for maintenance-free systems (e.g. heat pumps, gas) and manual operation options (e.g. wood).
- Existing or planned installation of PV (photovoltaics) or other renewable sources.
- Is the user interested in solutions that comply with the requirements of TC (Technical Conditions) 2021 (*Jakie normy musi spełniać nowy dom?*, 2021) (e.g. building energy standards) and ETS2 (*ETS 2: będzie opłata emisyjna od węgla, gazu i oleju opałowego*, 2024) (e.g. avoiding fossil fuels).

The expert system expects the above information in order to model the user's preferences and needs. The system processes and classifies this information, and then compares it with the data contained in the knowledge base. Based on the obtained results, LLM generates a recommendation regarding the most suitable heat source. The system also uses algorithms related to supplementing the data, initially provided by the user. If the system is unable to extract the above information or it is ambiguous, the system may ask the user to supplement the data. The expert recommendation system based on ChatGPT conducts reasoning by examining the compatibility of available heat sources with the user's preferences and needs. It takes into account both technical parameters and subjective user expectations. For this purpose, advanced recommendation algorithms are used, such as Content-Based Filtering, Collaborative Filtering, Hybrid Recommendation Systems, etc. (Roy & Dutta, 2022).

The configuration, testing and fine-tuning process began with the validation of data fed into the expert system. Validation was performed using prompts, asking questions about the types of heating systems, their parameters, advantages, disadvantages, additional requirements necessary for their installation and use. The expert system, based on the reasoning process, prepared answers to the questions posed to it. The next step was to check the requirements for houses intended for the installation of a heating system. Prompts were also used to regulate the importance of information influencing the choice of heating and the way of presenting information to the user. During the construction of prompts, methods designed specifically for LLM ChatGPT (Wei et al., 2022) were used.

The flow chart of the expert system construction process is presented in Figure 1.

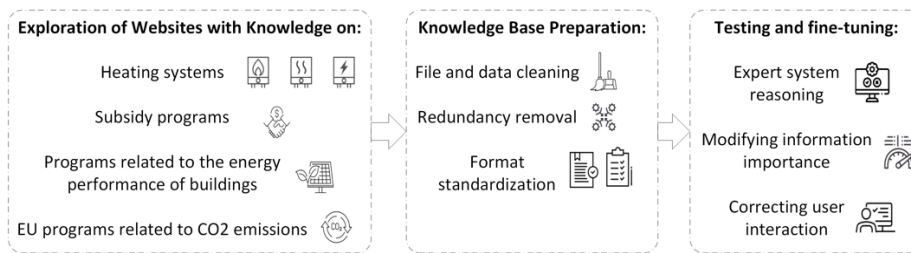


Figure 1. The expert system construction process recommending heat sources
Source: own elaboration.

3. RESULTS

3.1. Case study-based verification of the heat source recommendation system

In order to analyse the recommendation system, a study of four different cases was conducted. These cases differ in terms of the size and purpose of single-family houses, geographical locations and available energy sources. The lifestyle characteristics of families and their motivations, approach to ecology and workload on heating systems are also diverse. The case studies were taken from reality – they were based on real information about users and buildings. Three cases were ex-post – information was available about the type of heating actually chosen, recommended and implemented by industry specialists. In these cases, the expert system was required to confirm or question the heating technology used. The fourth case is ex-ante, and therefore presents a situation in which the user is just making a choice and has not yet consulted experts.

Case 1. A typical single-family house from the 1990s, located in the Łódź-Górna district. Masonry building, partially basement, area of 120 m². Classic layout of rooms: residential ground floor, usable attic. Medium insulation – insulation from a dozen or so years ago (10 cm), double-glazed windows, gravity ventilation. Radiator heating. The house is inhabited by retirees who were looking for a convenient and familiar solution – they decided to replace the old coal boiler with a modern condensing gas boiler. The proximity of the gas network and local subsidies made the decision easier.

- **Lifestyle:**
 - frugal, reluctant to making big changes, but value comfort.
- **Information from the owners:**
 - After retiring, they wanted a warm and safe home without firing the stove every day.
 - They chose a familiar system – gas with the “golden mean” between costs and comfort.
 - They did not use the subsidy, but they used the thermal modernization relief.
- **Building parameters:**
 - Area: 120 m².
 - Standard: good (EUco ~80 kWh/m² per year).
 - Installation: steel radiators, domestic hot water from a boiler.
- **Conditions:**
 - Location: city, access to the gas network.
 - Priorities: comfort, proven technology.
 - Budget: PLN 35,000.

Case 2. A modern, Energy-efficient bungalow with an area of 180 m², located on the outskirts of Gdańsk (Osowa district). The building was built using prefabricated technology, with very good insulation and ventilation with heat recovery. Underfloor heating throughout the house, Smart Home system with energy consumption monitoring. The owners – young professionals from the IT industry – planned a low-energy house with a ground heat pump and PV installation from the very beginning. The ground is conducive to installing vertical probes. High costs are balanced by almost zero bills and high thermal comfort.

- **Lifestyle:**
 - very environmentally conscious, interested in new technologies and investments in RES.

- **Information from the owners:**
 - From the beginning, they wanted to build a house in line with the “house without bills” principle.
 - They had a larger budget and treated the house as a long-term project.
 - They wanted a completely emission-free system that would meet standards for decades.
 - They use smart control, monitoring and automation system.
- **Building parameters:**
 - Area: 180 m².
 - Standard: TC 2021 + recuperation, EUco = 50 kWh/m² per year.
 - Heating system: underfloor heating throughout the house.
- **Conditions:**
 - Location: Gdańsk (mild climate).
 - Access to RES: yes, PV option.
 - Priorities: efficiency and long-term savings.
 - Budget: up to PLN 100,000.

Case 3. A wooden Scandinavian-style recreational house located in the mountain village of Przesieka in the Karkonosze Mountains. Area of 90 m², ground floor with a mezzanine. The building is used mainly in weekends and during holiday periods. Well insulated (graphite polystyrene, mineral wool), natural ventilation, low heat demand. Open interior, no boiler room, with southern exposure. The owners – a couple from Wrocław – value silence and simplicity. Due to the lack of gas and small heating needs, they decided on heating with infrared foils – a maintenance-free, comfortable and aesthetic solution.

- **Lifestyle:**
 - minimalist, they like nature and silence, they don't want to waste time on servicing devices.
- **Information from the owners:**
 - The house is to be a place of rest – the lack of a boiler room and noise was crucial.
 - The heating foils met their aesthetic expectations (invisible, no radiators).
 - Operating costs were secondary, but the lack of the need for servicing was an advantage.
 - They plan to install PV to completely eliminate bills.
- **Building parameters:**
 - Area: 90 m².
 - Standard: good insulation (EUco ~55 kWh/m² per year).
 - Use: seasonal (spring-summer-autumn + winter weekends).
- **Conditions:**
 - Location: mountainous, no gas, low temperatures.
 - Priorities: simplicity, maintenance-free, low investment.
 - Budget: PLN 20,000.

Case 4. A single-family detached house, located in Opole, Opole voivodeship (2nd climate zone). Area of 130 m². The building after thermal modernization in 2023. The owner prefers a maintenance-free heating system.

- **Lifestyle:**
 - comfortable, maintenance-free.
- **Information from the owners:**
 - No maintenance required.
 - Clean and cheap heating.
 - Openness to RES.
 - Willingness to use subsidies – yes (‘Clean Air’).
- **Building parameters:**
 - Area: 130 m².
 - Standard: thermal modernization in 2023 – insulation of walls (15 cm), attic (20 cm), new triple-glazed windows, gravitational ventilation, low-temperature radiators (after modernization).

- **Conditions:**

- Location: natural gas – none, Space for fuel – none, electricity – available, 18 kW connection, no restrictions.
- Budget: up to PLN 30,000.

3.2. Solutions proposed by the expert recommendation system

Case 1. The expert system confirmed that a condensing gas boiler was the best choice for this specific case. The rationale for this choice was supported by the appropriate analysis. The system drew attention to ETS2 (future emission fees) and the direction of changes in the EU related to the planned departure from subsidizing gas boilers. It proposed an alternative in the form of an air-to-water pump with the support of PV and noted a significant increase in the budget and the need to modernize the installation in this case.

Case 2. The system determined the selected solution as the best for the given parameters. It justified this choice and provided estimated annual fees for such an installation. It checked and provided the amounts possible to obtain from the ‘My Heat’ subsidy. It drew attention to compliance with TC 2021 standards and possible future EU regulations (Fit for 55). The system provided a possible alternative (air-to-water heat pump or hybrid pump with PV and Energy storage) and suggested the selection of a specific ground-source pump, preparation of a cost estimate taking into account subsidies and calculation of annual costs.

Case 3. In this case, the expert system also confirmed the correctness of the heat source selection under the given conditions. The system provided its advantages, estimated installation and operating costs, and compliance with RES. The system suggested extending the heating system with remote control and a heat buffer, as well as the possibility of selecting PV based on energy balance. Alternative heating methods (heat pump, pellet/wood/biomass, LPG/oil) were also discouraged along with the justification.

Case 4. Since in this case the owner did not receive a recommendation for the expert – he is open to any solution. The expert system proposed a solution based on heating foils and a PV installation. He justified his choice by indicating the main advantages of this solution in the context of the studied case. Heating foils are maintenance-free – ideal for a user who values comfort. They do not generate CO₂ emissions, so they will not be covered by ETS2 fees. The use of heating foils in combination with PV allows to reduce heating costs even to zero. The system considered this solution to be ideal for a well-insulated house after thermal modernization, also indicating the speed of installation without the need to modernize the boiler room or fuel storage. The investment budget, around PLN 28–30,000, can be obtained in its entirety from the ‘Clean Air’ program. Moreover, in the long term, heating foils are resistant to future EU regulations (no fossil fuels, 100% electric energy sources). All these elements were raised by the expert system, recommending heating foils as the right solution.

4. COMPARISON OF THE OPERATION OF THE DEVELOPED EXPERT SYSTEM WITH THE ORIGINAL VERSION OF CHATGPT 4O

Case 1. Although both the expert system and the original GPT 4o model recommend a condensing gas boiler, there are fundamental differences in their operation. The first difference are the questions in the expert system supplementing knowledge with information concerning:

- availability of an electrical connection with a capacity greater than 10–12 kW,
- planned investments in PV,
- avoidance of fossil fuels in connection with ETS2,
- availability of space for potential storage of solid fuels (wood, pellet).

The above questions are presented in Figure 2.

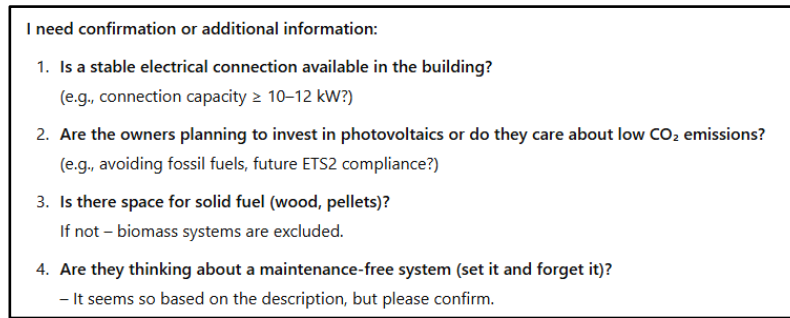


Figure 2. Questions employed by the expert system to gather more detailed information – case 1
Source: chatgpt.com.

Further differences occur in the calculated operating costs. The expert system estimates annual heating costs at PLN 7,500 – 8,500 based on the current gas price, while the original ChatGPT 4o reports annual heating costs in the range of PLN 2,500 – 3,500, which is a significant underestimation. The expert system informs about the planned CO₂ emission fees from 2027 and about the lack of subsidies for gas boilers from 2025. The original ChatGPT 4o does not take this information into account. The differences between the recommendations are shown in Figure 3.

Both systems provide a heat pump (air-to-water) as an alternative. The original version additionally proposes a pellet boiler (without knowledge of the possibility of storing fuel) and electric heating + PV as an alternative. In turn, the expert system compares the current annual heating and investment costs for natural gas, heat pump and pellet. As the final information, the expert system proposes preparing an application for a thermal modernization allowance, checking the possibility of switching to a hybrid system and simulating costs for the next 10 years in the comparison of gas vs. heat pump. The original ChatGPT 4o only offers a cost summary and an estimated calculation for annual heating costs. These differences are shown in Figure 4.




<p>a)</p> <p> ANALYSIS & RECOMMENDATION</p> <p> 1. GAS CONDENSING BOILER – Chosen option & very good match</p> <p>Why it's a good fit:</p> <ul style="list-style-type: none"> • Compatible with the existing radiator system • Fully automatic, quiet, and convenient • Compact and familiar system, especially for seniors • Annual heating cost (120 m², EUco 80): approx. 7,500–8,500 PLN (at current gas prices ~0.40 PLN/kWh) • Within the planned budget (35,000 PLN) <p>Risks:</p> <ul style="list-style-type: none"> • From 2027, carbon emission fees (ETS2) will apply – lower than for coal or oil • No subsidies for fossil fuel boilers after 2025 and full phase-out by 2040 • Gas prices might rise after deregulation in 2027 <p>Overall assessment:  A solid compromise between cost, comfort, and familiar technology</p>	<p>b)</p> <p>Recommended Solution: Condensing Gas Boiler</p> <p>Reason for Selection:</p> <ul style="list-style-type: none"> • Seniors are looking for a maintenance-free and proven system. • Natural gas is available (urban location with access to the gas network). • Familiarity with the technology – gas is a "golden mean" between cost and comfort. • Possibility to deduct costs through the thermomodernization tax relief. • A radiator-based heating system is already in place – a gas boiler can be easily integrated with the existing installation. <p>Estimated Costs:</p> <ul style="list-style-type: none"> • Boiler + installation + system upgrade: PLN 25,000–30,000. • Operating costs: moderate (~PLN 2,500–3,500 annually for EUco ~80 kWh/m²/year).
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Figure 3. Recommendations of (a) the expert system and (b) the original ChatGPT 4o – case 1
Source: chatgpt.com.

<p>a)</p> <p>ANNUAL COST SUMMARY (for 120 m², EUco 80 kWh/m²/year):</p> <table border="1"> <thead> <tr> <th>System</th> <th>Annual heating + DHW costs</th> <th>Investment</th> </tr> </thead> <tbody> <tr> <td>Natural gas (condensing)</td> <td>approx. 7,500 – 8,500 PLN</td> <td>approx. 25–35 thousand PLN</td> </tr> <tr> <td>Air-to-water heat pump</td> <td>approx. 6,000 – 7,000 PLN</td> <td>approx. 40–55 thousand PLN (with buffer and installation)</td> </tr> <tr> <td>Pellet (eco-project)</td> <td>approx. 7,000 – 7,500 PLN</td> <td>approx. 20–30 thousand PLN + physical maintenance</td> </tr> </tbody> </table>	System	Annual heating + DHW costs	Investment	Natural gas (condensing)	approx. 7,500 – 8,500 PLN	approx. 25–35 thousand PLN	Air-to-water heat pump	approx. 6,000 – 7,000 PLN	approx. 40–55 thousand PLN (with buffer and installation)	Pellet (eco-project)	approx. 7,000 – 7,500 PLN	approx. 20–30 thousand PLN + physical maintenance	<p>b)</p> <p>◆ Alternative 1: Air-to-water heat pump</p> <p>Only under the condition that:</p> <ul style="list-style-type: none"> The budget can be increased (actual cost is approx. PLN 40–45 thousand, including radiators). Certain modernization works are acceptable (e.g., larger radiators or a heat buffer). <p>Notes:</p> <ul style="list-style-type: none"> In the current insulation standard and radiator layout, a heat pump may not operate efficiently (high supply temperature required). Requires preparation of the DHW (domestic hot water) system – additional cost. Requires greater user involvement during the configuration stage. <p>Consider this option if:</p> <ul style="list-style-type: none"> The household is open to modern technologies. External support is increased (e.g., "Clean Air" program subsidy + thermomodernization relief). <hr/> <p>◆ Alternative 2: Pellet boiler</p> <p>Not recommended in this case because:</p> <ul style="list-style-type: none"> Requires regular fuel refilling (even if semi-automatic). Requires space for the storage and handling of pellets. Seniors clearly prefer maintenance-free solutions. <hr/> <p>◆ Alternative 3: Electric panel heating + PV</p> <p>Only possible if a photovoltaic system is installed; however:</p> <ul style="list-style-type: none"> Requires larger investments (> PLN 50 thousand in total). In the current building standard, operating costs could be too high without significant PV installation. A major change for people used to traditional heating systems.
System	Annual heating + DHW costs	Investment											
Natural gas (condensing)	approx. 7,500 – 8,500 PLN	approx. 25–35 thousand PLN											
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Pellet (eco-project)	approx. 7,000 – 7,500 PLN	approx. 20–30 thousand PLN + physical maintenance											
<p>c)</p> <p>Final recommendation:</p> <p>Sticking with the new condensing gas boiler is the most reasonable choice in this situation.</p> <p>It fits your lifestyle, installation, and expectations. In the future—if the need arises—a heat pump can be added in a hybrid system.</p> <p>Would you like me to:</p> <ul style="list-style-type: none"> calculate a 10-year cost simulation for gas vs. heat pump? check the possibilities of switching to a hybrid system? prepare a template for an application for a thermomodernization allowance or for the "Clean Air" program? 													
<p>d)</p> <p>Final Conclusion</p> <p>The most suitable solution is:</p> <p>A gas condensing boiler, adapted to the existing radiator system, with priority given to domestic hot water (DHW).</p> <p>This solution is optimal in terms of comfort, cost, and alignment with the owners' lifestyle. It fits within the budget, does not require a major reconstruction of the installation, and meets the most important needs: a warm home, convenient operation, and low technological risk.</p> <p>If needed, I can also prepare a cost breakdown and an estimated calculation of annual heating expenses – should I include that?</p>													

Figure 4. Other differences between the expert system and the original ChatGPT 4o – case 1: (a) costs of alternative heat sources according to the expert system, (b) alternative options suggested by ChatGPT-4o, (c) conclusions of the expert system (d) conclusions of ChatGPT-4o
Source: chatgpt.com.

Case 2. As in the previous case, the expert system asked for the missing information:

- year of construction of the house,
- what is the power connection capacity,
- whether an application for the 'My Heat' program is planned.

Both systems recommended a ground source heat pump with vertical probes and a PV system. In addition, the original ChatGPT 4o model recommended an Energy storage as an additional option (despite exceeding the budget). The original ChatGPT 4o estimated the PV installation power at 9 – 10kWp compared to the power of 7 – 9kWp proposed by the expert system. The original ChatGPT estimated the cost of the entire investment at PLN 85,000 – 105,000 compared to the cost of PLN 95,000 – 125,000 (PLN 65,000-90,000 including the 'My Heat' subsidy) predicted by the expert system. These differences result primarily from differences in the estimated costs of PV and a pump with vertical probes. The original ChatGPT 4o estimated the cost of PV (9 – 10kWp) at PLN 25,000 – 30,000, and the cost of purchasing and installing a pump with probes at PLN 55,000-65,000. In turn, the author's expert system assumed the cost of PV (5 – 7kWp) at the level of PLN 25,000 – 35,000, and the cost of a pump with probes – PLN 70,000 – 90,000. Comparing this to offers on the market, it should be noted that the expert system estimated the costs more accurately. There are also differences in the calculation of the subsidy. The expert system calculated subsidies in the amount of PLN 21,000 ('My Heat' program) and PLN 10,000 of thermal modernization relief. In turn, the original ChatGPT 4o only informed about the possibility of reducing costs by about 10-30%, without providing information about specific aid programs. Figure 5 presents all the differences.

<p>a)</p> <p><input checked="" type="checkbox"/> Investment Costs (Estimate):</p> <table border="1"> <thead> <tr> <th>Installation Component</th> <th>Gross Cost (est.)</th> </tr> </thead> <tbody> <tr> <td>Ground source heat pump (10–12 kW)</td> <td>PLN 55,000 – 70,000</td> </tr> <tr> <td>Vertical boreholes (2x80 m)</td> <td>PLN 15,000 – 20,000</td> </tr> <tr> <td>Photovoltaics (5–7 kWp)</td> <td>PLN 25,000 – 35,000</td> </tr> <tr> <td>TOTAL gross</td> <td>approx. PLN 95,000 – 125,000</td> </tr> </tbody> </table> <ul style="list-style-type: none"> • Grant from "My Heat" program – PLN 21,000 • Thermomodernization tax relief (at 17% PIT) – approx. PLN 10,000 <p>Effective total cost after grants approx. PLN 65,000 – 90,000</p>	Installation Component	Gross Cost (est.)	Ground source heat pump (10–12 kW)	PLN 55,000 – 70,000	Vertical boreholes (2x80 m)	PLN 15,000 – 20,000	Photovoltaics (5–7 kWp)	PLN 25,000 – 35,000	TOTAL gross	approx. PLN 95,000 – 125,000	<p>b)</p> <p>5. Estimated Budget (Budget: up to PLN 100,000)</p> <table border="1"> <thead> <tr> <th>Item</th> <th>Estimated Net Cost</th> <th>Notes</th> </tr> </thead> <tbody> <tr> <td>Ground source heat pump + probes</td> <td>PLN 55,000–65,000</td> <td>Depending on depth and contractor</td> </tr> <tr> <td>PV installation 9–10 kWp</td> <td>PLN 25,000–30,000</td> <td>Depending on components and installation</td> </tr> <tr> <td>Extended Smart Home system</td> <td>PLN 5,000–10,000</td> <td>Integration with sensors and automation</td> </tr> <tr> <td colspan="3">TOTAL: PLN 85,000–105,000</td> </tr> <tr> <td colspan="3"><i>Before potential subsidies</i></td> </tr> </tbody> </table> <p>Note: It is possible to reduce the cost by approx. 10–30% through subsidy programs.</p>	Item	Estimated Net Cost	Notes	Ground source heat pump + probes	PLN 55,000–65,000	Depending on depth and contractor	PV installation 9–10 kWp	PLN 25,000–30,000	Depending on components and installation	Extended Smart Home system	PLN 5,000–10,000	Integration with sensors and automation	TOTAL: PLN 85,000–105,000			<i>Before potential subsidies</i>		
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Figure 5. Recommendations of (a) the expert system and (b) the original ChatGPT 4o – case 2
 Source: chatgpt.com.

As the last piece of information, the expert system suggested the selection of specific heat pump + PV sets (specific brands) or calculating after how many years this investment will pay off in relation to, for example, gas heating. Moreover, the system offered assistance with submitting an application for funding under the "My Heat" program. The original ChatGPT 4o suggested comparing the selected heat source to a system with an air-to-water pump or without an energy source. Figure 6 shows the differences between the final conclusions of the expert system and those of the original ChatGPT-4o.

<p>a)</p> <p><input checked="" type="radio"/> What's next?</p> <ol style="list-style-type: none"> 1. I can help select a specific heat pump model (e.g., Nibe, Vaillant, Viessmann) 2. Calculate the energy balance and determine the required PV capacity 3. Recommend installation companies and explain how to apply for the "Moje Ciepło" subsidy <p>Would you like me to prepare a detailed investment schedule or a cost estimate with variants?</p>	<p>b)</p> <p>7. Final Recommendations</p> <ul style="list-style-type: none"> • Investing in a ground-source heat pump and PV system is the most effective long-term solution within the given budget. • A detailed installation design is necessary (energy audit, geological analysis of the site). • It is worth considering energy storage integration to improve independence and security. <p>If desired, I can also prepare alternative variants (e.g., with air-source heat pump or without battery storage) for comparative analysis.</p>
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Figure 6. Final conclusions of (a) the expert system and (b) the original ChatGPT 4o – case 2
 Source: chatgpt.com.

Case 3. In this case, the expert system had sufficient data and did not ask for additional information. Both systems correctly determined the advantages of the recommended infrared foil heating and correctly calculated the budget. The difference occurred when calculating the seasonal heat demand (2 – 2.5 MWh according to the expert system and 1.5 – 2.5 MWh according to the original ChatGPT 4o). It should be noted here that the expert system's estimate was more precise. Additionally, the expert system determined the annual cost of electricity and suggested using PV to reduce this cost. The indicated differences between the recommendations are shown in Figure 7.

<p>a)</p> <p>Good building insulation and low EUco (~55 kWh/m²/year):</p> <ul style="list-style-type: none"> • This means low heating demand – approx. 5,000 kWh annually, i.e., around 2,000–2,500 kWh in practice with seasonal use. • Heating costs at the current electricity price (1 kWh ~ PLN 1.0): approx. PLN 2,000–2,500/year, but with PV, they can drop nearly to zero. 	<p>b)</p> <p>Technical parameters of the building:</p> <ul style="list-style-type: none"> • Floor area: 90 m², EUco ~55 kWh/m²/year – usable energy demand of approx. 4,950 kWh/year, which, given occasional use, realistically translates to 1.5–2.5 MWh/year. • Very good thermal insulation and a compact building form with southern exposure contribute to passive heat gains.
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Figure 7. Recommendations of (a) the expert system and (b) the original ChatGPT 4o – case 3
 Source: chatgpt.com.

In addition, the expert system suggested adding heating mats or infrared wall panels to critical points in the house. Both the expert system and ChatGPT 4o suggested calculating the operating costs in the summary (the expert system additionally after the potential installation of PV). In addition, ChatGPT 4o suggested determining the heating power for individual rooms. These options are shown in Figure 8.

<p>a)</p> <p>Optional Enhancements:</p> <p>If you're looking for additional comfort:</p> <ul style="list-style-type: none"> You can add heating mats in the bathroom or infrared wall panels in selected spots. Consider smart zoned control (e.g., Heat Decor Smart or others) to further save energy when no one is at home. <hr/> <p>Summary:</p> <ul style="list-style-type: none"> The current system (infrared heating foils) is optimal for a small, well-insulated recreational home with a planned PV installation and a priority on simplicity, aesthetics, and maintenance-free operation. No system change or expansion is required, only slight optimization is possible (e.g., control system, PV). <hr/> <p>If you'd like, I can calculate estimated operating costs after PV installation or suggest a specific controller or foil model – just let me know!</p>	<p>b)</p> <p>Summary:</p> <p>Infrared heating foils combined with a planned PV installation represent the optimal heat source for the analyzed building. This solution is:</p> <ul style="list-style-type: none"> fully aligned with the functional and aesthetic expectations of the owners, maintenance-free and reliable, cost-effective both in terms of investment and operation (especially after PV installation), well-suited to the building's usage profile and the climatic conditions of the region. <p>If needed, I can also prepare a comparison of operating costs and select the appropriate heating power for individual rooms. Would you like me to prepare such a breakdown?</p>
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Figure 8. Additional suggestions proposed by the expert system and the original ChatGPT 4o - case 3
Source: chatgpt.com.

Case 4. The biggest differences between the recommendations of the author's expert system and ChatGPT 4o were visible in case 4. The author's system suggested infrared heating foils and a PV installation, while ChatGPT suggested a monoblock air-to-water heat pump. These recommendations are presented in Figure 9.

Analysing expertly case 4 (house after thermal modernization, low-temperature radiators, no natural gas, no space for heating, maximum budget of PLN 30,000), we must note that heating foils + PV are a better solution. They are cheaper to install, less invasive and fully compatible with the owner's lifestyle, and in combination with PV – also cheaper to operate. However, if the initial conditions related to the budget were to be significantly changes (to twice the size), the monoblock heat pump suggested by ChatGPT would be more attractive, especially in combination with PV. However, it is worth noting that when the budget is raised to PLN 60,000, the expert system also recommends a heat pump, optionally combined with PV, as illustrated in Figure 10. However, this is a split pump, technically more advanced than a monoblock pump. This case confirms the advantage of the expert system recommendations over the recommendations of the original ChatGPT 4o.

A comparison of the basic recommendations generated by both systems is presented in Table 1.

<p>a)</p> <p>✔ Recommendation:</p> <p>Infrared heating foil (Heat Decor / Red Snake) + PV photovoltaic installation</p> <hr/> <p>🔥 Costs:</p> <p>📄 Investment:</p> <ul style="list-style-type: none"> Heating foil: ~300–350 PLN/m² of heated floor surface (e.g., ~18,000 PLN for 60 m² of active surface) PV 3.5–4 kWp: ~12,000 PLN Total: ~30,000 PLN <p>🕒 Annual operating costs:</p> <ul style="list-style-type: none"> Without PV: approx. 3,500–4,000 PLN/year (fully electric heating) With PV: ~0–800 PLN/year (depending on self-consumption and installation size) 	<p>b)</p> <p>✔ Recommendation:</p> <p>Air-to-water heat pump (monoblock) + low-temperature radiators (existing system)</p> <hr/> <p>🔥 Costs:</p> <p>📄 Investment:</p> <ul style="list-style-type: none"> Air-to-water heat pump monoblock (8–10 kW): ~21,000 PLN Hot water tank + buffer + installation accessories: ~9,000 PLN Installation and commissioning: ~5,000 PLN Total: ~35,000 PLN <p>🕒 Annual operating costs:</p> <ul style="list-style-type: none"> Approx. 1,900–2,100 PLN/year (based on energy consumption ~2,600 kWh/year and G12 tariff)
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Figure 9. Recommendations of (a) the expert system and (b) the original ChatGPT 4o – case 4
Source: chatgpt.com.

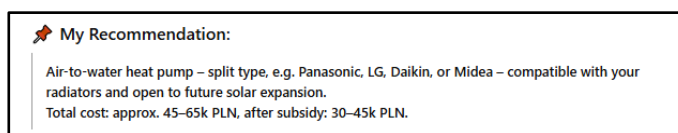


Figure 10. Expert system recommendation for a budget of PLN 60,000 – case 4
Source: chatgpt.com.

Table 1. Comparison of the expert system and ChatGPT recommendations – case 4

	Expert system – heating foils + PV	ChatGPT 4o – air-to-water heat pump
Investment cost	PLN 30,000	PLN 35,000
Service	None	None
Annual cost	Without PV: PLN 3,500-4,000 With PV < PLN 800	PLN 1,900-2,100
Disadvantages	No domestic hot water, a boiler needs to be added	Exceeds the budget
Subsidy	Yes	Yes
ETS2 ready	No emissions	Grid emissions (indirect)
Service/maintenance	None	Service every 2-3 years

Source: own elaboration.

4. CONCLUSION

Analysing the research results, it should be noted that in almost all cases both systems correctly recommended heat sources. The expert system, unlike the original ChatGPT, provided more precise calculations and more detailed data. The lack of or partial information provided by the original ChatGPT concerned subsidy programs, ETS2 and expected future costs. The information provided by the user was verified by the expert system in such a way that in the case of incomplete data, the system would ask for details. Thanks to this, the expert system reduced the risk of incorrect recommendations. Additionally, the form of recommendations provided was more user-friendly in the case of the expert system. The research results indicate that modifications of ChatGPT to the role of an expert system are of great importance. Attention should be paid to sociological techniques (approach to user knowledge and information provided by him) and to the creation of knowledge bases dedicated to specific types of recommendation systems. Further research will include the construction of knowledge bases and more advanced GPT-based expert systems related to other complex decision problems.

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