

TRNSYS - Dynamic Simulation of a Three-Zone House in Iași Heated and Cooled by an Air-Source Heat Pump

Simularea dinamică în TRNSYS 18 a unei case cu trei zone din Iași încălzită și răcită cu o pompă de căldură aer-sursă

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DOI: 10.37789/rjce.2026.17.3.8

Abstract: *This paper presents a TRNSYS 18 dynamic model of a three-zone dwelling in Iași, Romania, with a conditioned floor area of 224 m² and an enclosed volume of 747 m³. The model couples climate processing, solar-radiation conversion, ground interaction, a TRNBUILD multizone building, a thermostat, and an air-source heat pump. Using the uploaded annual plots, the study interprets incident solar radiation, indoor/outdoor temperatures, zone-specific heating and cooling loads, and heat-pump electricity use. The original contribution is the explicit mapping between TRNSYS component outputs and engineering indicators, together with a discussion of the current model-coupling limits and the pathway toward PV-battery integration.*

Key words: TRNSYS 18, air-source heat pump, residential building, heating and cooling loads

1. Introduction

Buildings remain a central energy and climate challenge. According to the International Energy Agency (IEA), building operations account for around 30% of global final energy consumption and 26% of global energy-related emissions, which makes the decarbonization of building services a strategic research priority [1]. In advanced economies, space and water heating still represent the dominant share of residential energy use [1]. Heat pumps are among the most promising electrification technologies for this transition. The IEA shows that heat pumps powered by low-emissions electricity are a central option for secure and sustainable heating, and that currently available units are typically three to five times more energy efficient than natural-gas boilers [2]. Their dual capability for space heating and cooling is especially

relevant for climates with both winter heating demand and increasingly important summer overheating periods [2]. For dynamic research problems that couple the building envelope, weather, control logic, renewable electricity and HVAC equipment, TRNSYS is particularly appropriate. The software is an iterative, component-based transient simulation environment widely used for thermal and electrical energy systems [3]. Within the standard library, TRNBUILD is the multizone building model linked to a TRNBuild description file, while the component library also supports ground-coupled boundary models and HVAC components [4].

The scientific literature already confirms the relevance of combining heat pumps with solar electricity and storage. Jonas et al. showed how TRNSYS can be used to model solar-thermal and heat-pump system configurations [5]. Bee et al. developed a TRNSYS model of a single-family house equipped with an air-source heat pump and photovoltaic system, highlighting the role of storage in self-consumption [6]. More recently, Gagliano et al. reported strong improvements in residential self-consumption and self-sufficiency when heat pumps were combined with electrical and thermal storage [7].

Similar conclusions were reached for net-zero-oriented residential PV–heat-pump sizing studies [8] and for hybrid battery concepts aimed at increasing photovoltaic self-consumption [9]. Review work also indicates that heat-pump systems integrated with solar technologies and storage are a robust pathway toward nearly zero-energy buildings [10]. Against this background, the objective of the present paper is to document and interpret a user-provided TRNSYS 18 model of a house located in Iași, Romania, with a total floor area of 224 m² and an enclosed volume of 747 m³. The manuscript follows the uploaded conference template and uses the attached TRNSYS scheme and annual plots to discuss (i) the structure of the simulation model, (ii) the equations used to convert raw TRNSYS outputs into engineering indicators, (iii) the annual behavior of solar forcing, indoor temperatures, zone-specific heating/cooling demands, and heat-pump electrical demand, and (iv) the implications of the current results for a future PV–battery extension of the model. Because the uploaded figure set does not include raw battery plots, the battery-related part is developed here as a model-ready framework rather than as a quantified annual result.

2. Content of the paper

2.1. Case study and TRNSYS model architecture

The uploaded case-study descriptor identifies a residential building placed in Iași, Romania, with a conditioned surface of 224 m² and a total enclosed volume of 747 m³. The TRNBuild screen capture shows a three-zone configuration, while the post-processing equations used in the Simulation Studio model indicate zone floor areas of 64 m² for Zone 1, 64 m² for Zone 2 and 96 m² for Zone 3. The annual simulation horizon is 8760 h, as confirmed by the horizontal axes of the uploaded online plotters.

The Simulation Studio scheme contains the following functional blocks: a settings block, a climate block, a radiation unit converter, a ground-coupled boundary/ground-

solar block, the multizone building block, an air-source heat pump, a room thermostat, a unit converter for post-processing, and four online plotters dedicated to solar radiation, temperatures, specific heating/cooling loads, and electrical power. The building block is consistent with TRNBUILD because the uploaded output list includes the standard TRNBUILD variables TAIR, TOP, QHEAT, QCOOL, QELEQUIP, and QELIGHT for each thermal zone.

The climatic data feed both the solar and thermal boundary conditions. The uploaded solar plot shows that the model tracks several surface orientations, including horizontal and tilted south, east, west, and north-facing surfaces. The ground-coupled block supplies a boundary temperature for the floor-side coupling, while the weather signals and the building state variables are exchanged with the heat pump and controller.

2.2. Control and post-processing logic

The room thermostat monitors room temperature and sends heating, cooling and conditioning control signals to the air-source heat pump. In parallel, the TRNBUILD building model provides ideal-load outputs for zone-level space heating and cooling. For publication purposes, the raw TRNSYS outputs were converted into specific loads (W/m^2) and electrical powers (kW) through a dedicated unit converter. This post-processing is important because the original building outputs are reported in kJ/h, while the heat-pump power outputs are also reported in kJ/h in the uploaded project configuration. The manuscript intentionally keeps the distinction between ideal building loads and physical plant-side electricity demand. The annual heating and cooling curves are derived from the building model (ideal zone loads), whereas the electricity plot is derived from the heat-pump block. This distinction is important when discussing model maturity: the envelope and ideal-load submodel can already be interpreted with confidence, while the plant-side annual synchronization still requires refinement before seasonal COP or PV-battery self-sufficiency indicators are reported.

2.3. Control and post-processing logic

The solar-radiation plot confirms a strong seasonal and orientation-dependent variability of the climate input in Iași. Graphical reading of the uploaded annual plot suggests that the maximum total and beam incident solar radiation approaches 1000 W/m^2 for the most favorably exposed surfaces during the warm season. This result is fully consistent with the need to represent separate facade and roof orientations when assessing mixed heating-cooling behavior. The temperature plot shows a large outdoor thermal amplitude, with ambient temperature visually ranging from approximately -15°C in winter to about 36°C in summer. In contrast, the zone air and operative temperatures remain in a much narrower band, generally clustering around roughly $18\text{--}26^\circ\text{C}$. The three thermal zones follow similar seasonal trends, but they are not

perfectly identical, which reflects both the zoning choices and the differences in exposed surfaces and roof participation visible in the TRNBuild model. The heating/cooling plot indicates a clearly heating-dominated annual behavior. The highest specific heating demand is observed in Zone 2, with graphical peaks close to 95–100 W/m², followed by Zone 3 at about 85–90 W/m² and Zone 1 at approximately 60–65 W/m². Cooling appears mainly during the middle of the year and is smaller in magnitude, with the most exposed zone reaching about 50–55 W/m² and the remaining zones typically remaining below about 25 W/m². The figure, therefore, shows that the building is substantially more constrained by winter heating than by summer cooling under the uploaded configuration. The electrical plot reveals that the compressor power during active periods is around 1.5–1.6 kW, while the total heat-pump electric power is almost superposed on the compressor curve. This suggests that fan contributions are comparatively small under the current operating conditions. However, the electrical activity appears concentrated only in part of the annual horizon, whereas the ideal-load plot exhibits both winter heating and summer cooling seasons. Scientifically, this mismatch is a useful result: it indicates that the present model already supports envelope-level and ideal-load analysis, but the full year-round coupling between TRNBUILD loads and the heat-pump control should still be refined before reporting annual system performance factors, grid exchange metrics or final battery self-sufficiency indicators.

2.4. Control and post-processing logic

The wider research objective indicated by the authors concerns a fully electrified residential system extended with photovoltaic generation and electrical storage. In that context, the current model is already suitable as the thermal core of the future study because it provides hourly weather forcing, thermal-zone demand, and plant-side power signals. The battery state of charge, production-consumption balance, excess electricity and grid exchange can therefore be added consistently on top of the present framework. Because the uploaded figure set available for this article does not contain explicit battery plots, the battery part is formulated below through general governing equations and discussed as an immediate continuation of the validated thermal model, not as a completed quantitative result.

3. Equations

The main equations used for the interpretation of the uploaded TRNSYS results are listed below. Equations (1)–(3) describe the generic thermal-control logic, Equations (4)–(7) reproduce the exact engineering post-processing used in the uploaded TRNSYS model, and Equations (8)–(9) provide the battery-ready extension for the future integrated electric system.

$$C_z \frac{dT_z}{dt} = \sum_j U_j A_j (T_{\{s,j\}} - T_z) + \dot{m}_{\{inf,z\}} c_p (T_{\{amb\}} - T_z) + \dot{Q}_{\{sol,z\}} + \dot{Q}_{\{int,z\}} + \dot{Q}_{\{HVAC,z\}} \quad (1)$$

$$u_{\{h,z\}} = 1, \text{ if } T_{\{air,z\}} < T_{\{set,h\}}; \quad u_{\{h,z\}} = 0, \text{ otherwise} \quad (2)$$

$$u_{\{c,z\}} = 1, \text{ if } T_{\{air,z\}} > T_{\{set,c\}}; \quad u_{\{c,z\}} = 0, \text{ otherwise} \quad (3)$$

$$q_{\{ht,z\}} = Q_{HEAT_z} / (3.6 A_z), \text{ with } A_1 = 64 \text{ m}^2, A_2 = 64 \text{ m}^2, A_3 = 96 \text{ m}^2 \quad (4)$$

$$q_{\{cl,z\}} = Q_{COOL_z} / (3.6 A_z) \quad (5)$$

$$P_{\{comp\}} = \text{Compressor\ Power} / 3600, \quad P_{\{el,tot\}} = \text{Total\ Energy\ Input} / 3600 \quad (6)$$

Implemented TRNSYS converter equations: $q_{ht_1}=[56,3]/3.6/64$; $q_{cl_1}=[56,4]/3.6/64$;
 $q_{ht_2}=[56,9]/3.6/64$; $q_{cl_2}=[56,10]/3.6/64$; $q_{ht_3}=[56,15]/3.6/96$;
 $q_{cl_3}=[56,16]/3.6/96$; $HP_comp_kW=Input1/3600$; $HP_total_kW=Input2/3600$ (7)

$$SOC_{\{k+1\}} = SOC_k + \eta_{\{ch\}} P_{\{ch\}} \Delta t / E_{\{bat\}} - P_{\{dis\}} \Delta t / (\eta_{\{dis\}} E_{\{bat\}}) \quad (8)$$

$$P_{\{PV\}} + P_{\{grid\}} + P_{\{dis\}} = P_{\{HP\}} + P_{\{aux\}} + P_{\{ch\}} + P_{\{exp\}} \quad (9)$$

Main symbols: A_z – floor area of zone z ; C_z – effective thermal capacitance of zone z ; c_p – specific heat of air; E_{bat} – nominal battery capacity; $m_{inf,z}$ – infiltration mass-flow rate; P_{ch}/P_{dis} – charge/discharge power; P_{exp} – exported electrical power; P_{grid} – imported grid power; P_{HP} – heat-pump electrical demand; $\dot{Q}_{HVAC,z}$ – heat added to or removed from zone z ; $q_{ht,z}$ and $q_{cl,z}$ – specific heating and cooling loads; SOC – battery state of charge; $T_{air,z}$ – zone air temperature; $T_{set,h}$ and $T_{set,c}$ – heating and cooling setpoints.

4. Tables

The main input data, variable mappings and graphically interpreted annual results are summarized in the following tables.

Table 1

Case-study building and simulation information

Item	Value
Location / Conditioned floor area	Iaşi, Romania / 224 m ²
Enclosed volume / Number of thermal zones	747 m ³ / 3
Zone floor areas	Zone 1 = 64 m ² ; Zone 2 = 64 m ² ; Zone 3 = 96 m ²
Building model / Plant model	TRNSYS TRNBUILD / TRNBuild multizone building / Air-source heat pump with room thermostat
Boundary-condition processing / Simulation horizon	Climate block, radiation unit converter, and ground-coupled/ground-solar block / 8760 h (annual)

Item	Value
Main reported outputs	Incident solar radiation, ambient and indoor temperatures, specific heating/cooling loads, heat-pump electric power

Table 2

TRNSYS output mapping and post-processing equations used in the article

Indicator	TRNSYS origin	Post-processing equation	Final unit
q _{ht,1}	TRNBUILD output [56,3]	[56,3]/3.6/64	W/m ²
q _{cl,1}	TRNBUILD output [56,4]	[56,4]/3.6/64	W/m ²
q _{ht,2}	TRNBUILD output [56,9]	[56,9]/3.6/64	W/m ²
q _{cl,2}	TRNBUILD output [56,10]	[56,10]/3.6/64	W/m ²
q _{ht,3}	TRNBUILD output [56,15]	[56,15]/3.6/96	W/m ²
q _{cl,3}	TRNBUILD output [56,16]	[56,16]/3.6/96	W/m ²
HP _{comp_kW}	Unit converter Input1 from Compressor Power	Input1/3600	kW
HP _{total_kW}	Unit converter Input2 from Total Energy Input	Input2/3600	kW

Table 3

Approximate annual results graphically interpreted from the uploaded TRNSYS plots

Variable / indicator	Approximate graphical value	Interpretation
Maximum total / beam incident solar radiation	up to ~1000 W/m ²	Strong summer solar availability and strong orientation dependence.
Outdoor ambient air temperature	Approximately -15 °C to 36 °C	Cold-heating and warm-cooling seasons are both present in Iași climate conditions.
Zone air / operative temperature band	Mostly ~18 °C to 26 °C	Indoor temperatures vary much less than ambient temperature, confirming the moderating effect of the envelope and ideal-load control.
Peak specific heating load – Zone 1	about 60–65 W/m ²	Heating demand is high in winter but lower than in Zones 2 and 3.
Peak specific heating load – Zone 2	about 95–100 W/m ²	Zone 2 is the most heating-demanding zone in the current configuration.
Peak specific heating load – Zone 3	about 85–90 W/m ²	Zone 3 also has strong winter demand, slightly below Zone 2.
Peak specific cooling load –	about 50–55 W/m ²	Cooling is present mainly in the middle of the year

Variable / indicator	Approximate graphical value	Interpretation
most exposed zone		and remains lower than winter heating.
Heat-pump compressor power during active periods	about 1.5–1.6 kW	Electrical power is dominated by compressor demand.
Difference between total and compressor electric power	very small in the uploaded plot	Fan contributions appear modest compared to compressor power.

Table 4

Melting points and basic analyzes

Compuși	Mp(°C)	Formula chimică	N(%)	
			Calc.	Rezultat
3A	178	C ₂₉ H ₃₄ N ₂ O	6.57	6.70
3B	264	C ₂₉ H ₃₃ N ₃ O ₃	8.92	8.85
3C	232	C ₂₉ H ₃₂ N ₄ O ₅	10.85	10.78
5A	185	C ₂₉ H ₃₄ N ₂ O	6.56	6.41
5B	242	C ₂₉ H ₃₃ N ₃ O ₃	8.92	8.87
5C	245	C ₂₉ H ₃₂ N ₄ O ₅	10.85	10.63

5. Figures

The figures below are reproduced from the uploaded TRNSYS project material and the corresponding online plotter screenshots.

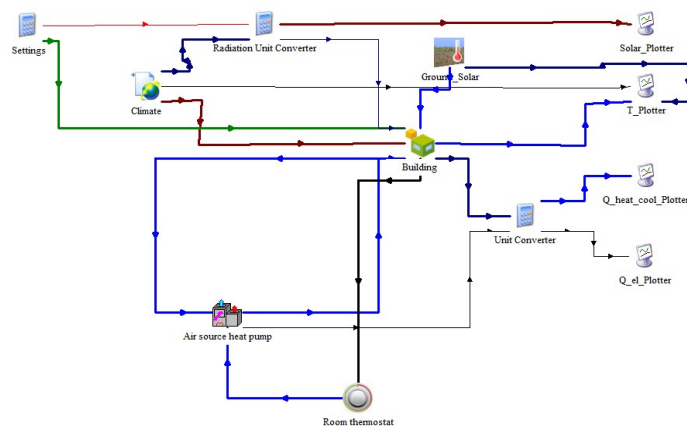


Fig. 1. TRNSYS 18 Simulation Studio scheme used for the case-study building, including climate processing, radiation conversion, ground interaction, multizone building model, room thermostat, air-source heat pump, and online plotters.

Each figure is announced by an insertion marker, as requested, and is followed by its centered caption.

TRNSYS - Dynamic Simulation of a Three-Zone House in Iași Heated and Cooled by an Air-Source Heat Pump

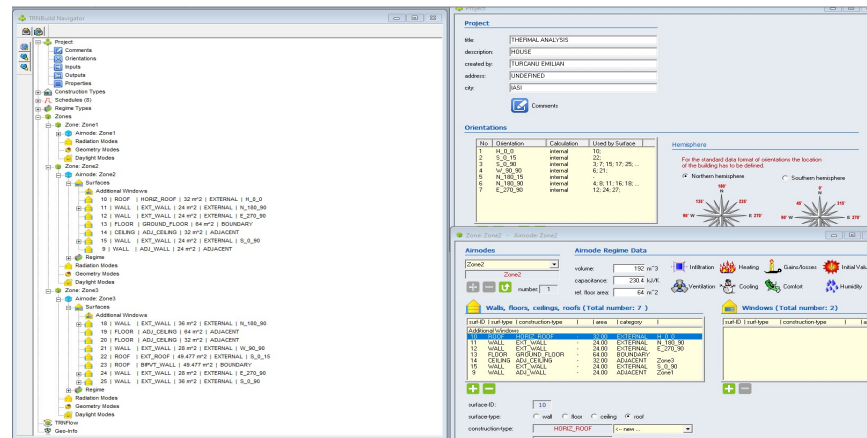


Fig. 2. TRNBuild view of the case-study building, showing the project setup, zone structure, orientations, and surface definitions used to generate the TRNBUILD building description file.

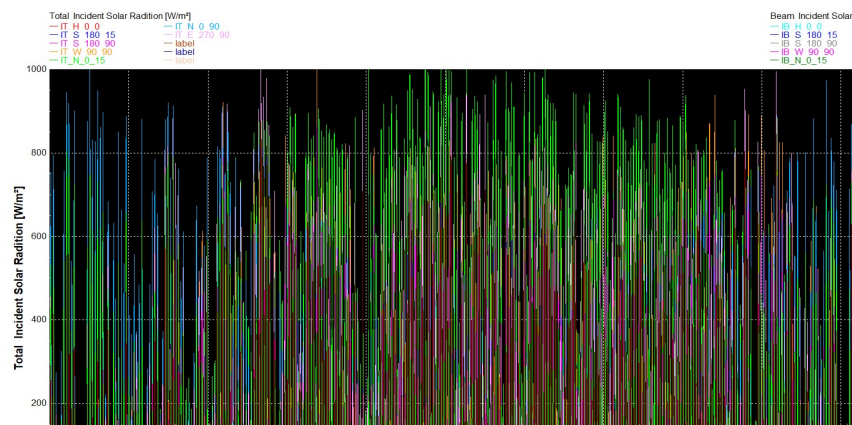


Fig. 3. Annual total and beam incident solar radiation on the modeled orientations, as provided by the TRNSYS online solar plotter.

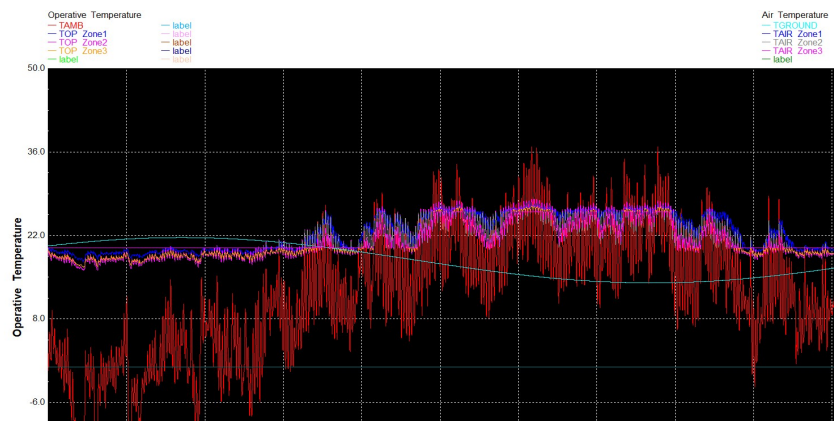


Fig. 4. Annual outdoor ambient temperature together with the air and operative temperatures of the three thermal zones.

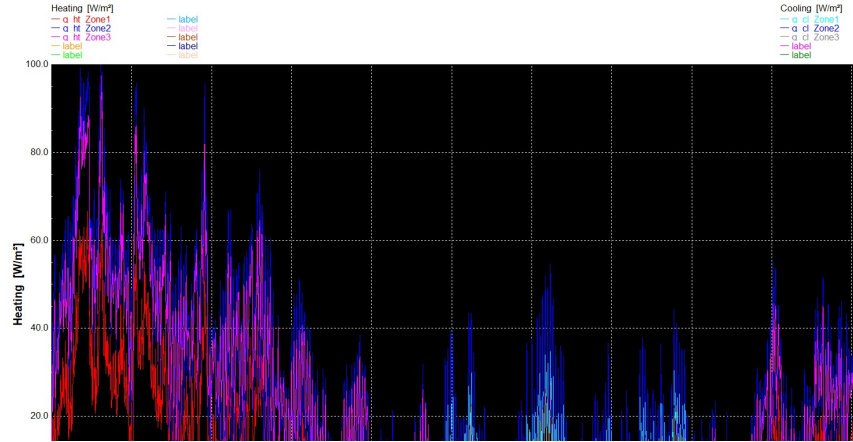


Fig. 5. Annual specific heating and cooling loads of the three zones, post-processed from the TRNBUILD building outputs.

6. Conclusions

The uploaded TRNSYS 18 model supports a coherent dynamic interpretation of a three-zone residential building located in Iași, Romania. The building-level part of the model is already mature enough to provide meaningful annual results for incident solar radiation, indoor thermal response, and zone-specific space-conditioning loads.

The annual plots show a clearly heating-dominated case study. Specific winter heating peaks are strongest in Zone 2, followed by Zone 3, while summer cooling is present over a shorter period and at smaller magnitudes. The ambient climate exhibits a broad annual range, but the indoor temperatures remain confined to a much narrower interval, confirming the damping effect of the envelope and the ideal-load formulation in the building model.

The air-source heat pump electrical plot indicates active compressor demand of roughly 1.5–1.6 kW during the operating windows captured by the uploaded results, while the total electrical power almost overlaps the compressor curve. This suggests that the compressor dominates the electric consumption under the current operating conditions.

At the same time, the uploaded figures reveal an important modeling insight: the ideal TRNBUILD thermal loads and the physical heat-pump electrical activity are not yet fully synchronized over the entire year. Therefore, the current project version is scientifically suitable for envelope/load analysis and controller debugging, but it should be further refined before deriving annual SPF/COP, grid-exchange or battery-autonomy indicators from the same coupled deck.

The next research step is straightforward: the validated thermal core can be extended with photovoltaic generation, electrical storage, state-of-charge tracking, production-consumption balance, and excess-energy indicators. Once the battery plots or raw hourly output files are exported from TRNSYS, the manuscript can be extended

from the present thermal-and-plant assessment to a full PV–battery–heat-pump self-consumption and self-sufficiency study.

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