Influence of Primary Power Source on Heat-insulating Material Choice for Autonomous Telecom Unit Container

S Kiseleva¹, A Tarasenko²* and A Fedotov³
¹ Joint Institute for High Temperatures of the Russian Academy of Sciences, Moscow, Russian Federation
² Lomonosov Moscow State University, Faculty of Geography, Moscow, Russian Federation
³ National Research University Moscow Power Engineering Institute, 17/3 Krasnokazarmennaya Street, 111250 Moscow, Russia

E-mail: a.b.tarasenko@gmail.com

Abstract. The paper is devoted to the energy balance estimation for autonomous telecom unit, powering from photovoltaic panels and diesel-fuelled genset. Unit container has its own heat balance, basing on climate control system and parasite heating from telecom equipment inside it. Climate control system is also considered as power consumer from PV or genset. Obviously this power consumption depends on unit load graph, heat exchange with environment, environmental temperature. Energy and economical analysis has been conducted for several possible unit geographical locations, three types on heat-insulating materials and different share of solar energy in energy balance. It has been shown that in case of diesel fuel domination in energy balance and not very low environmental temperature heat-insulating material with lowest heat conductivity is not an optimal choice from operational expanses point of view (through high fuel consumption in summer for the container cooling).

1. Introduction
Problems of electric power supply for remote territories have been of great interest for many years. Diesel genset is a traditional solution of problem. Coupling it with photovoltaic panels usually solves ecology and financial problems [1]. Climate issues, concerned with severe temperature ranges, are also taken into account [2]. Telecom basic units are one of the most widespread remote power consumers. And they need uninterrupted power supply in 24/7 mode [3]. This research is devoted to the operation of telecom basic unit (repeater) powered from diesel genset combination with PV panels and battery. Different locations of unit in Russia are considered. The issues of climate control inside the unit container are also taken into account.

2. Materials and methods
Unit includes repeater itself, container with telecom equipment and climate control system (split) which can be operated as heater or air condition unit depending on temperature in container. It is assumed that temperature range (plus 5 – plus 25)°C is suitable for telecom equipment inside the container. Electric load graph for power supply system consist power fed to repeater and to climate-control system. Typical operation diagram for repeater is taken from [4] and is assumed to be similar for the every day of the year. It is given in Figure 1. Peak power (100%) is assumed to be 3 kW.
Container for telecom equipment consists of sandwich-type panels and has dimensions of 4000*2500*2400 mm [5]. Sandwich-type panels have thickness of 110 mm.

Figure 1. Basic load graph for telecom repeater.

Heat sources inside the container are:
- **repeater** with efficiency $\eta = 83\%$ [6], generated heat during $\Delta t$ is

$$Q_1 = \eta \cdot P_{tr} \cdot \Delta t,$$

where $P_{tr}$ – averaged consumed electric power during $\Delta t$, taken from Figure1 for every hour (calculation step is 1 h);
- **heat-exchange** with the environment through the container walls and roof. All heat flows are assumed to be equal and independent from the direction. Penetrated or lost heat is:

$$Q_2 = k \cdot \frac{S}{l} \cdot (T_{out} - T_{in}) \cdot \Delta t,$$

where $k$ stands for heat-exchange coefficient, $S$ – total area of heat-exchange, $l$ – heat-insulating media thickness, $T_{out}$ – environment temperature (is taken from [7] for every day of the year and processed according to [8] to obtain hour data), $T_{in}$ – temperature inside the container, stabilized by split:

$$k = \frac{1}{\frac{2}{\alpha} + \frac{1}{\lambda}}$$

Here $\lambda$ stands for panel’s material heat conductivity, $\alpha$ – for air inside the container heat transfer coefficient.
- **split operation** for heating or cooling of the air inside the container. Generated heat is equal to:

$$Q_3 = C \cdot m \cdot (T_2 - T_{in}),$$
where $C$ is air heat capacity, $m$ – air mass inside the container, $T_2$ is air temperature inside the container for the previous hour of calculation. $T_{in}$ is derived from

$$Q_1 + Q_2 + Q_3 = 0$$

(5)

Then $Q_3$ is calculated, taken into account condition, that plus 5°C ≤ $T_{in}$ ≤ plus 25°C.

Values of $Q_2$ and $Q_3$ can be both negative and positive. Negative $Q_3$ value means that cooling is needed. In this case electric power consumption is estimated as 1 kWh of electric power for 3.2 kWh of heat (cooling) power. Positive $Q_3$ value means need heating and electric power in this case equals to needed heat.

Three approaches to telecom unit electric power supply are considered:

1) Diesel genset (G). In this case 2 gensets of equal power output are included in capital expenses due to one of them is needed to be in reserve. Here for every hour power output of genset is equal to needed electric power. Nominal power of genset used can be changed, but in case if needed power is more, than genset nominal power, load cannot be covered by such genset. Specific fuel consumption of genset is calculated for every hour depending on ratio of operated power to nominal power, according to [9].

2) Diesel genset coupled with PV panels (SG). Control system similar to SMA fuel save controller is supposed to be installed [10]. Diesel genset power cannot be lower than adjusted value (40% of nominal power), so power output of PV panels is lowered in case of low load. PV panels power output is estimated basing on [7, 8] similarly to [11]. As in [12], PV inverter efficiency depends on the translated power of PV array. PV array power also is a parameter, that can be changed for optimization.

3) Diesel genset coupled with PV panels and lead-acid battery (SGB). Battery efficiency equal to 85% [13] is taken into account in this case. Unit is fed from PV array (estimated as in case 1) and from battery, charged by excess PV output. In case if battery charge left has value of 40% of nominal energy capacity (can be optimized during calculation), genset is operated at its nominal power to feed the load and charge the battery. Such approach is supposed to decrease specific fuel consumption and CO₂ emissions at low power operation.

For every scheme total fuel consumption, number of genset service periods (1000 h of nominal operation) are estimated for 2-year period (2012-2013 actual data from [7]). Operation expenses for 10 year period are obtained multiplication of consumed fuel cost and service costs by 5. Costs for diesel fuel in Russian regions are taken from [14]. Capital costs for every scheme are estimated as sum of scheme components used. Initial prices for OPzV Lead-acid batteries, PV array mounting poles and gensets are obtained averaging data from [15]. Currency exchange course is assumed to be 70 russian roubles (RUR) for 1 US dollar (USD). For PV panels electrical and temperature parameters of Yingli-250YL were used in calculation.

3. Results and discussion

Calculation of capital and operation expenses for 3 types of power plant, feeding telecommunication unit (G – genset, SG – PV+genset, SGB – PV+genset+battery) have been taken for 4 locations in Russia. Locations included Palana (Kamchatka region with many remote consumers), Arkhangelsk (Northern port with low insolation and low temperatures), Mirny (Yakutia region with extremely low temperatures), Lago-Naki (Krasnodar region near Black Sea cost, where PV-feed telecom unit is already installed). Peak electric energy consumption was estimated as 3.4 kWe, PV array size is taken equal to 5 kWe and battery bank is of 32 kWh (8 h feed) lead-acid batteries OpZV type. Genset power output is equal to 4 kWe. Actual prices for diesel fuel for all regions were taken from [14]. Two types of commercial heat-insulating materials for telecom unit container were used – Plastmigran with specific heat conductivity of 0.08 W/m*K and Korund with 0.012 W/m*K. The results are given in Table 1.
Table 1. Technical and economic characteristics of power sources when using liquid heat-insulating media Korund (0.012 W/(m*K)) and solid heat-insulating media Plastmigran (0.08 W/(m*K)). Fuel Consumption for 10 years, tons – FC; Total Expenses for 10 years, th. USD – TE-10.

|                  | Palana (Kamchatka region)a | Mirnyb | Arkhangelsc | Lago-Naki (Krasnodar region)d |
|------------------|----------------------------|--------|-------------|-----------------------------|
| **Heat-insulating media Korund** | SGB | 28 | 36 | 26 | 44 | 28 | 42 | 29 | 41 |
|                  | G   | 198 | 106 | 195 | 180 | 198 | 147 | 205 | 145 |
|                  | SG  | 53  | 40  | 53  | 60  | 53  | 51  | 53  | 50  |
| **Heat-insulating media Plastmigran** | SGB | 25  | 34  | 23  | 41  | 25  | 38  | 27  | 39  |
|                  | G   | 184 | 98  | 177 | 162 | 182 | 135 | 193 | 137 |
|                  | SG  | 55  | 41  | 56  | 62  | 55  | 51  | 53  | 50  |

a Fuel price: 34000 rur/t [https://www.benzin-price.ru/price.php?region_id=41]
b Fuel price: 60700 rur/t [https://www.benzin-price.ru/price.php?region_id=14]
c Fuel price: 48500 rur/t [https://www.benzin-price.ru/price.php?region_id=29]
d Fuel price: 46270 rur/t [https://www.benzin-price.ru/price.php?region_id=23]

Calculation results showed that for all regions, due to high share of energy spent on equipment cooling, heat-insulation material with the best properties is not an optimal choice in case when G or SGB is used as energy source (Figure 2).

**Figure 2.** Power balance for Mirny during winter and summer model day.
In case of SG better heat-insulating media properties lead to equal or lower fuel consumption due to the fact that PV array can be operated only during day hours (in case of SGB significant part of solar-given energy can be transferred to night because of battery presence), when environmental temperatures are higher. Diesel fuel in SG scheme is usually consumed at night, when low environmental temperatures and low heat emission from repeater are seen. So for SG good container heat insulation is essential. For G and SGB schemes there is no significant difference for day and night energy consumption because of the constant genset operation or battery presence – solar energy during day can be absorbed into the battery and spent at night. Possibilities of SGB scheme to absorb solar energy are quite higher than for SG, because of limitations in SG scheme not to operate diesel genset at low power. Increase of fuel consumption for G and SGB scheme in case of better heat insulating media properties can be explained by domination of power consumption for cooling, not for heating during the whole year.

Results from Table 1 also showed that SGB scheme with 8-10 h possibility of battery operation, despite higher capital expenses can provide much lower fuel consumption and total expenses in 10-year period.

4. Conclusion
Several electric power feeding schemes, including diesel genset, PV array and lead-acid battery, were numerically estimated for remote telecom repeater container in 4 Russian regions with different climate conditions. Issues of climate-control inside the container due to telecom equipment heat emissions and their influence on load graph have been taken into account. Two heat-insulating medias with quite different heat conductivity have been considered in estimations. Calculation showed that application of PV array can significantly decrease diesel fuel consumption and total expenses for power supply of the remote user. Battery application leads to further fuel consumption decrease, but growth of capital expenses impedes the total costs decrease. Energy consumption for climate control appeared to be significant. For diesel genset, coupled with PV array without battery, is essential to provide good heat-insulation of the telecom equipment container because of the night diesel genset operation mainly for heating. For schemes with single genset and PV-genset-battery higher quality of heat-insulating material led to higher total diesel fuel consumption because of high energy consumption for cooling in spring, summer and autumn time. Difference between night and day consumption in this case is small, because battery increases solar energy absorption during day and allows its consumption at night.

Acknowledgments
This research has been conducted as a part of RAS Joint Institute for High Temperatures basic research program.

5. References
[1] Salameh T, Ghenai C, Merabet A and Alkasrawi M 2020 Energy 74 116475
[2] Li C, Zhou D, Wang H, Cheng H and Li D 2019 Energy 185 671–81
[3] Khan M J, Yadav A K and Mathew L 2017 Ren. Sust. Energ. Rev. 76 577-607
[4] Cellular radiotelephone communications as hygiene-significant electromagnetic field source. URL: http://www.vrednost.ru/pole.php
[5] Block-container catalogue. URL: http://krial.nt-rt.ru
[6] PicoCell 900 SXL repeater manual. URL: www.shop.mmw.ru
[7] NASA Prediction Of Worldwide Energy Resources Official Website. URL: https://power.larc.nasa.gov/data-access-viewer/
[8] Duffie J A and Beckman W A Solar Engineering of Thermal Processes, Fourth Edition. Hoboken, New Jersey: John Wiley & Sons, Inc. 910
[9] Soto D 2018 En. Sust. Dev. 45 180-85
[10] SMA Solar Technologies GmbH official Web-site. URL: https://www.sma.de/en/products/monitoring-control/sma-hybrid-controller.html

[11] Gabderakhmanova T S, Kiseleva S V, Frid S E and Tarasenko A B 2016 J. Physics: Conf. Ser. 774 1-10

[12] Kolomiets Yu G, Menshikov Ya A, Tarasenko A B 2018 Appl. Sol. En. 54(4) 246–50

[13] Tarasenko A B, Fedotov A A 2019 IOP Conf. Ser.: Mater. Sci. Eng. 564 012137

[14] Prices for benzene and oil products in Russian regions. URL: https://www.benzin-price.ru/price.php

[15] Your solar home LLC official Web-site. URL: https://shop.solarhome.ru/