In plant factories, LED lighting fixtures significantly contribute to energy consumption around 40 to 50% [Montes Rivera, Martín, Nivia Escalante-García, José Alonso Dena-Aguilar, Ernesto Olvera-Gonzalez and Paulino Vacas-Jacques. “Feature Selection to Predict LED Light Energy Consumption with Specific Light Recipes in Closed Plant Production Systems.” *Applied Sciences* (2022): n. pag. doi: 10.3390/app12125901] , it also serve as a primary source of heat (80%) that directly impacts the cooling load on air conditioning systems [Hai, Bin, Yu., Haiye, Yu., Bo, Zhang., Yuanyuan, Sui. (2023). Quantitative Perturbation Analysis of Plant Factory LED Heat Dissipation on Crop Microclimate. Horticulturae, doi: 10.3390/horticulturae9060660]

. Efficient removal of heat generated by LEDs not only alleviates the cooling load on air conditioning systems, thereby reducing overall energy consumpt, but also holds promise for enhancing the luminous efficacy of the LEDs themselves. Actually it is a common knowledge the luminous efficacy of LEDs decreases with increasing temperature in junction and thermal resistance of LEDs. [Quispe, M R, F Oscco, Martin John Horn and M M Gómez. “Influence of the temperature of a white LED on its lighting characteristics.” *Journal of Physics: Conference Series* 2538 (2023): n. pag. doi: 10.1088/1742-6596/2538/1/012009] [Peng, Dongsheng and K L Liu. “Effect of ambient temperature and heating time on high-power LED.” *Journal of Physics: Conference Series* 1777 (2021): n. pag. doi: 10.1088/1742-6596/1777/1/012033] [Markowicz, Marek, Emil Smyk and Robert Smusz. “Experimental study of the LED lamp.” *MATEC Web of Conferences* (2021): n. pag. doi:10.1051/MATECCONF/202133801015] . Furthermore, Yuan et al. proved after about 800 hours of working, the luminous efficiency of the LEDs decreased significantly, meaning the duration of operation time of LEDs is also crucial for its luminous efficiency. [Fei Yuan, Kailin Pan, Yu Guo and Shujing Chen, “Study on thermal degradation of high power LEDs during high temperature and electrical aging,”  2013 10th China International Forum on Solid State Lighting (ChinaSSL)\_, Beijing, 2013, pp. 150-153, doi: 10.1109/SSLCHINA.2013.7177336.]

By discussing the heat losses in phosphor-converted LEDs, researchers like Lisitsyn et al. emphasizes that reducing energy losses caused by heating is crucial for enhancing the luminous efficacy of LEDs. [Lisitsyn, Viktor M., V. S. Lukash, Sergey Stepanov and Ju Yangyang. “White LEDs with limit luminous efficacy.” (2016). doi: 10.1063/1.4937863] .

所以led灯散热量的有效处理不仅事关冷负荷也就是能耗，也跟led自身芯片可持续运行息息相关。

Presently, cooling technologies for LED components mainly encompass air cooling, water cooling, and immersion cooling methods [Matthew, T., Siedhoff. (2022). Immersion Cooling of Suspended and Coated Nano-Phosphor Particles for Extending the Limits of Optical Extraction of Light Emitting Diodes. Journal of Heat Transfer-transactions of The Asme, doi: 10.1115/1.4055568]

Air cooling techniques have reached a notable level of maturity in electronics cooling applications, characterized by relatively high COP (Coefficient of Performance)

https://doi.org/10.1016/J.APPLTHERMALENG.2016.03.056.

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; With LED being also an electronic device, direct application of air-cooling heatsinks can address the heating issue associated with LEDs; however, the heat dissipated from LEDs still permeates into indoor air, affecting temperature and humidity control, rendering it an incomplete solution to the problem at hand.

Y. Lai et al proved with experiments that active liquid cooling is an effective solution for high brightness LEDs in automotive headlights, outperforming air cooling and passive liquid cooling methods. [Y. Lai, N. Cordero, F. Barthel, F. Tebbe, J. Kuhn, R. Apfelbeck and D. Wurtenberger. “Liquid cooling of bright LEDs for automotive applications.” *Applied Thermal Engineering*, 29 (2007): 1239-1244. https://doi.org/10.1016/J.APPLTHERMALENG.2008.06.023.]

Water cooling technology is widely adopted and boasts higher efficiency in computer server applications, with COPs reaching up to 20 【7】; it is particularly suitable for scenarios with dense heat loads. Nonetheless, when implemented in plant factories, water cooling requires overcoming challenges such as transferring heat across multiple layers of growing racks (which necessitates pump-powered propulsion) and ensuring effective outdoor heat expulsion (which demands additional energy input from pumps) 【8】.

Although utilizing nutrient solutions for cooling purposes in plant factories presents some feasibility, it confronts numerous challenges: if no independent piping system is added and heat transfer relies solely on conductive contact between LED lights and growth racks, it may negatively affect the growth conditions for plants. Conversely, installing additional pipe routes to dissipate heat outdoors before entering the growth racks effectively resembles constructing an independent water cooling system, which would prevent rapid rises in nutrient solution temperatures should the water cooling system fail 【9】.

In summary, using nutrient solutions for cooling introduces more complexity and is not the most efficient or energy-saving thermal conduction option 【10】. Furthermore, while immersion cooling exhibits excellent heat dissipation properties, its effectiveness cannot be harnessed under heating conditions because the cooling liquids typically used are detrimental to plants 【11】.

Based on the above discussion, this paper proposes a novel cooling solution aiming to:

* Design and implement an efficient heat conduction mechanism for LED aluminum substrates, rapidly removing the generated heat.
* Transfer this heat to a sustainable heat storage pool designed for directional discharge to the outdoor environment.

The ultimate objectives envisioned are:

* Achieving zero-energy cooling of LED chips during cooling operations;
* Recouping and reusing waste heat generated by LEDs without compromising their light output performance under heating conditions.