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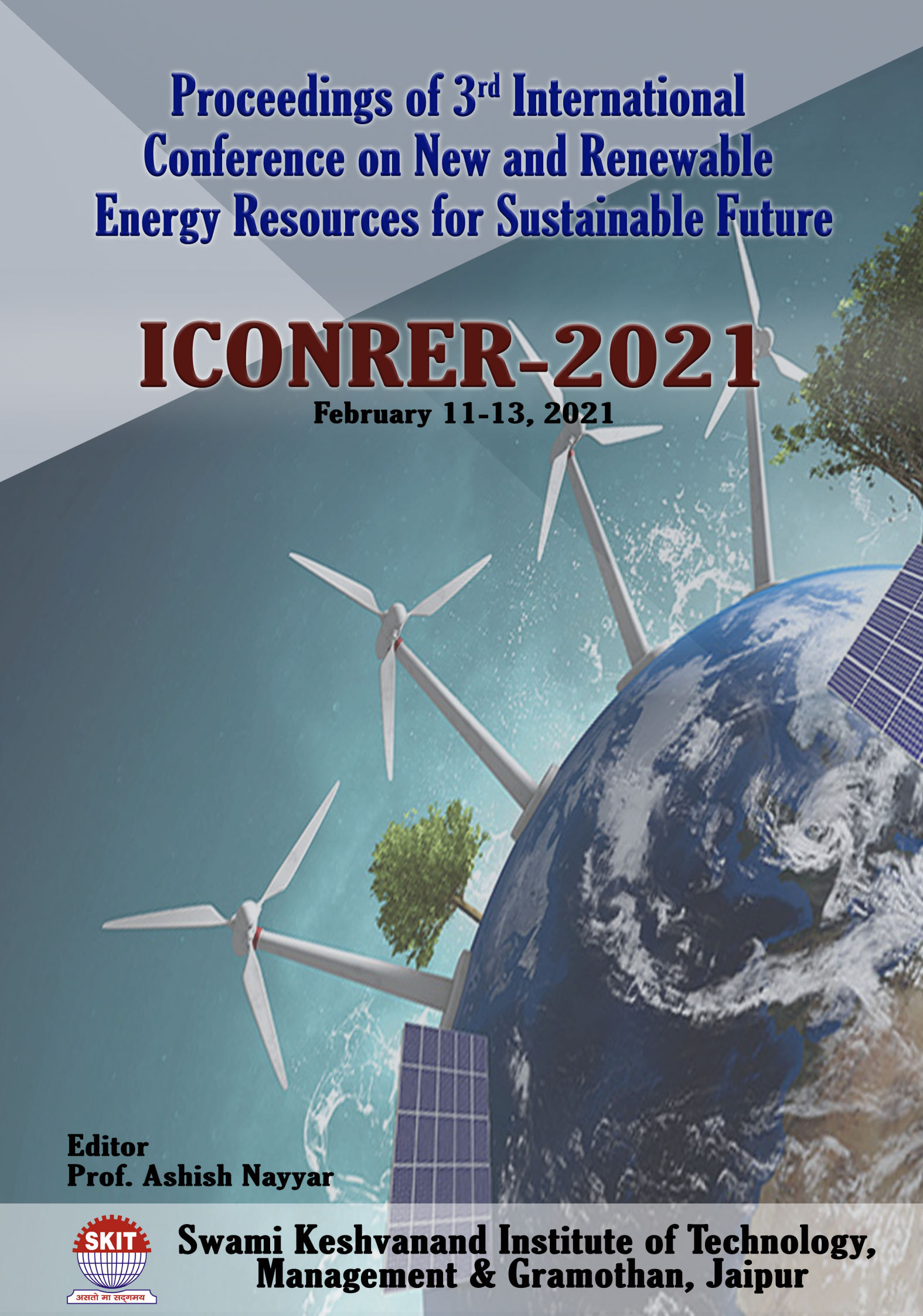

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SCENARIO OF COOLING SYSTEMS POWERED BY SOLAR ENERGY IN INDIA

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Abstract

Increasing urbanization, rising incomes and large cooling demand prompted by India's hot, humid climate are driving increase uptake of room air conditioners (ACs). ACs already accounts for 40 – 60% of summer peak load in large Indian cities such as Delhi and projected to contribute 140 GW (~30%) to peak demand by 2030. However, India's standards and labeling polices improved the market average efficiency of room ACs by 35% between 2006 and 2016 (3% per year), that is just half compared to that across the developed nations. Improving efficiency needs to be complemented by other strategies that reduce cooling demand, low cost efficient auxiliary equipments, and alternative options such as cooling system driven by solar energy either thermally or electrically.

In this context, India is endowed with rich solar energy resource in form of high intensity solar irradiation (200 MW/km^2) available during average 2700 sunshine hours per year. At present, India's solar PV electricity generation capacity is increased by 370% in last 3 years and further planned to achieve 175 GW by 2022. In addition to this, a considerable progress has been noticed with the installation of Solar thermal based cooling system mainly vapor absorption based. Nearly 150 solar thermal based cooling energy generation plants are installed and targeted to achieve capacity of 5 million square meter solar collector area and 25000 TR solar cooling by 2022. Ministry of New and Renewable Energy is also promoting solar thermal based cooling systems by offering 30% subsidy along with additional 15% offered by UNDP-GEF.

This research projects a comprehensive picture of the initiatives and research progress in energy conservation and management. Starting with a background of energy scenario, the article covers policy level measures and research and development activities reported so far. This review reveals that even though there are promising climate conditions and policy supports, the country has wide scope for effective research activities, public awareness and strong implementation to promote solar based air conditioning.

Keywords: **solar thermal cooling; solar photovoltaic cooling; subsidy; energy scenario.**

INTRODUCTION

Air conditioning is the dominating energy-consuming service in buildings in many countries. In fact, in many regions of the world, the demand for cooling and dehumidification of indoor air is growing due to increasing comfort expectations and increasing cooling loads[1]. A recent national socio-economic census indicates that economic and social deprivations are much higher in terms of availability of proper houses, access to education, lifeline availability of energy, and stable sources of income. This is more so in rural India where 48% of the households lack basic socio economic services and were categorized as deprived [2].

India's hot, humid climate prompts substantial demand for space cooling, and air conditioner (AC) use is increasing rapidly with the country's rising incomes and increasing urbanization [3]. Room ACs account for 99% of all ACs purchased, and their sales have grown at a compounded annual growth rate (CAGR) of 12.5% per year between 2005 (1.3 million) and 2014 (3.7 million) [3] [4] [5]. An AC is highly electricity intensive; at full load, a typical room AC consumes about 150 times the power of a light-emitting diode (LED) bulb or 20 times the power of a regular ceiling fan. Because many parts of India routinely experience extremely hot temperatures, increasing the availability and affordability of space-cooling technologies including fans and ACs is (along with improving building design to ensure thermal comfort) an important opportunity to improve health and economic well-being.

In the absence of additional policy interventions, i.e., under a business-as-usual (BAU) scenario, room AC penetration is expected to rapidly increase in India and could add about 140 GW to the peak demand (equivalent to about 300 power plant units of 500 MW each) by 2030 and between 300-500 GW by 2050 [5] [6] these values are equivalent to about 30% of the projected peak loads in 2030 and 2050 [7] [8]. Multi-model results show that limiting total human-induced warming to less than 2°C relative to the period 1861-1880 with a probability of more than 66% would require cumulative CO2 emissions from all anthropogenic sources since 1870 to remain below about 2900 GtCO2 (with a range of 2550-3150 GtCO2 depending on non-CO2 drivers). About 1900 GtCO2 had already been emitted by 2011 [2]. If all efforts are put to tap above potential, 5 million sq. m. of solar collectors area with 25,000 TR (tons of refrigeration) is possible to achieve by 2022 for solar cooling [1].

India is endowed with rich solar energy resource. The average intensity of solar radiation received on India is 200 MW/km square (megawatt per kilometre square) with average sunshine hours of 2700hrs/year. With a geographical area of 3.287 million km square, this amounts to 657.4 million MW. However, 87.5% of the land is used for agriculture, forests, fallow lands, etc., 6.7% for housing, industry, etc., and 5.8% is either barren, snow bound, or generally inhabitable. Thus, only 12.5% of the land area amounting to 0.413 million km square can, in theory, be used for solar energy installations. Even if 10% of this area can be used, the available solar energy would be 8 million MW, which is equivalent to 5 909 mtoe (million tons of oil equivalent) per year. Nearly 150 Solar absorption systems installed in India have been reported till 2014, most of them are hybrid systems coupled with auxiliary heating source. At present, 30% subsidy is offered by government for solar thermal based project along with additional 15% by UNDP-GEF with a target to increase total installed capacity to 5 million square meter solar collector area and 25000 TR solar cooling till 2022.

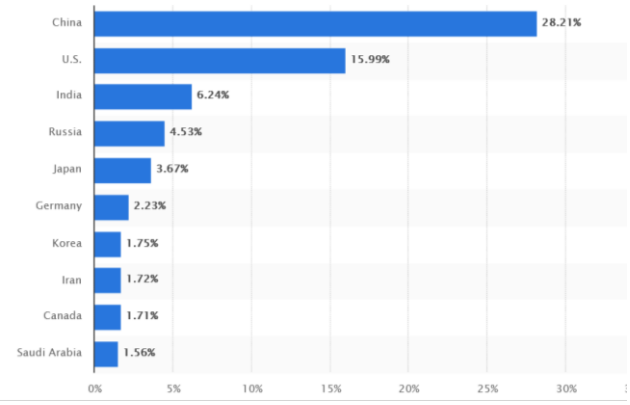

Figure 1 Country wise CO_2 emissions share country wise based on their global CO_2 emission share 2016 [9]

This research projects a comprehensive picture of the initiatives and research progress in energy conservation and management in the Indian building sector. Starting with a background of energy scenario, the article covers the policy level measures and research and development activities reported so far. High initial investment, less public awareness and weak implementation of green energy building initiatives are required to sort out in order to enhance solar cooling capacity. This review reveals that even though there are promising climate conditions and policy supports, the country has wide scope for effective research activities, public awareness and strong implementation to promote solar based air-conditioning.

ISSUES AND CHALLENGES

The renewable energy which will be used in low temperature applications, under the consideration of low operating cost, high availability and non-polluted emission such as solar energy is of great importance in the domestic as well as industrial lookup. Solar energy can be used as power sources for cooling systems, especially for the absorption and adsorption chiller. India is located in the area where the solar intensity is very high and thus solar energy can be used as power sources. The absorption chiller using water/lithium bromide is the most appropriate for the solar applications. This system, however, is not widely used in India due to its complexity, high toxicity caused by leakage and high initial cost. The utilization of absorption chiller may increase if more researches focus on the development of this cooling system, which is driven by solar energy. This may results in a substantial decrease in electricity consumption. Utilizing solar energy is very attractive since the cooling requirements are in phase with the solar energy availability. Using solar driven air conditioners would also reduce the dependence on fossil fuel based energy. The collector area is found to be the key parameters in reducing the payback period of the initial investment. Moreover, the proposed system is found to reduce 12 metric tons/year of CO_2 emissions due to its energy savings.

At present, no solar cooling system can be considered a viable substitute for the conventional systems. Among all the solar systems considered, the absorption system is the most promising and the cost difference between that system and the conventional systems declines steadily as occupancy increases.

SOME OF THE RECENT PROJECTS

There are large-scale air conditioning systems using roof top mounted parabolic troughs and triple effect VAMs being built at a scale of 100 kW and more. These systems are typically water-cooled centralized air-conditioning with chilled water circulated through air handling units. Since space is at a premium, getting maximum cooling from minimum area is important. Integration of the triple-effect chiller with medium temperature solar collectors achieved 30% reduction in space along with 20% extra cooling as compared to other solutions. This solution also has relevance to industries that have process cooling requirements.

TERI's biomass gasifier (50 kWe) is coupled with Thermax's newly developed Vapour Absorption Machine (VAM) of 15 kW cooling capacity and concentrating solar parabolic dishes. This system can provide clean power and cold storage facility for about 25 tons of fruits and vegetables. Since the cold storage can be cooled to temperatures as low as 0 °C, it is able to a store a wide variety of fruits, vegetables, and horticultural produce. The biomass gasifier produces 50 kWe electricity producing exhaust heat at 400 °C. About 70% of this waste heat can be recovered to generate hot water at 135 °C for the VAM of 15 kW capacity system for cold storage. Four

Scheffler dishes with aperture area of 16 m² each have been integrated to provide thermal energy for operation of the chiller during sunny hours of the day.

GOVERNMENT INITIATIVES TO PROMOTE SOLAR COOLING TECHNIQUES

Government of India is way forwarding the benefits of adopting solar energy as clean sources of energy and thus promoting the solar based installations. These are majorly based on the solar PV technology but installation rate of solar thermal cooling setups is also high. Thus, subsidy for solar PV installations has played an important role in order to promote the monetary benefits of installing a roof top solar PV plant. In addition to this, solar thermal installations have been given subsidy to improve the awareness about energy savings through these. A total of 30% subsidy to all categories of beneficiaries with additional benefit of 80% accelerated depreciation to profit-making bodies is available from the MNRE for installations. Higher subsidy for special category states is available. In addition, up to 15% support is available from UNDP-GEF project for systems sizing 250 sq. m. and above for specific activities.

The following initiatives have been taken by government to promote Solar Power in the country:

- Exemption from excise duties and concession on import duties on components and equipment required to set up a solar plant
- A 10-year tax holiday for Solar Power Projects.
- Wheeling, banking and third party sales, buy back facilities by states.
- Guaranted market through solar power purchase obligation to states.
- GBI schemes for small projects connected to grid below 33 kV.
- Reduced wheeling charges as compared to those for conventional energy.
- Special incentives for exports from India in renewable Energy technology under renewable energy sector- specific SEZ.
- A payment security mechanism to cover the risk of default by state utilities/discoms.
- A subsidy of 30% of the project cost for off-grid solar thermal projects, subject to availability of funds.

In the Budget 2015, Government of India has announced a target of adding 175 GW of renewable energy, including addition of 100 GW of solar power, by the year 2022. It is also being planned to increase the Renewable Purchase Obligations to the levels as envisaged under National Action Plan on Climate Change (NAPCC). The Minister further stated that, subsidy of 30% of the benchmark cost for general category States and 70% for special category states is being provided also under off grid Solar PV program for grid connected Solar Rooftop, subsidy of 30% of the benchmark cost for general category States and 70% for special category States is being provided for defined category and subjected to availability of funds, the Minister added [10].

In the US typical household power consumption is about 11,700 kWh each year, in France it is 6,400 kWh, in the UK it is 4,600 kWh and in China around 1,300 kWh. The global average electricity consumption for households with electricity was roughly 3,500 kWh in 2010 [11].

Officially 84% of solar cell and module imports into India in the 2015-16 came from China. These imports amounted to $1.96bn in value. The dominant role that Chinese solar manufacturers currently play in the soaring Indian PV market was laid bare. Of the $2.34 billion worth of solar equipment brought into India over FY 2015-16, a massive $1.96 billion worth of solar cells and modules were produced in China. India is poised to become the world's third-largest solar market in the world next year, with analysts in agreement that the country will likely support 10 GW of growth over the coming few years. To achieve its longer-term goal of 100 GW of solar PV capacity by 2022, India will have to bolster its domestic manufacturing capacity, which currently stands at around 6.5 GW for modules and 1.6 GW for cells according to recent data from Mercom

Capital. Average capacity utilization across India is 82%, with Waaree, Vikram Solar and Emmvee each with an operating capacity of around 500 MW. Tata Power Solar and Alpex Exports have 300 MW and 250 MW capacity respectively.

Beyond the top-level manufacturers, some 600 MW of India's solar manufacturing capacity is ring fenced by a number of small players with less than 25 MW capacity each. These firms often own old and inefficient lines that are unlikely to be able to offer the kind of quality and affordability in solar components that India is increasingly demanding. Chinese solar modules, on the other hand, are being sold in India for around $0.39/watt, which is among the cheapest average selling price (ASP) anywhere in the world, according to Mercom Capital [12].

CONCLUSION AND FUTURE SCOPE OF WORK

This review reveals that even though there are promising research activities, policy supports and growing public awareness, the nation has wide scope for further developments in order to ensure (through the utilization of its resources at their fullest potential) that all the viable state-of-the-art technologies for energy conservation and management in this direction are implemented. Accordingly, a consolidated outline of the key areas in the domain is presented, and many potential new research directions are proposed in this work.

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Renewable energy and sustainable development are the key technologies to offer solutions to the ever-increasing environmental pollutions and depleting conventional fuel reserves. With an aim to discuss the state of art technologies pertaining to the renewable energy domain, RTU (ATU) TEQIP III Sponsored 3rd International Conference on New and Renewable Energy Resources for Sustainable Future (ICONRER-2021) was organized by the Department of Mechanical Engineering, Swami Keshvanand Institute of Technology, Management and Gramothan, Jaipur in collaboration with Rajasthan Technical University and Department of Mechanical Engineering, Assiut University, Assiut (Egypt) from February 11 to 13, 2021. ICONRER is a series of the conference started in 2017 and it was 3rd event of that series.

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