

Refining energy sources in winemaking industry by using solar energy as alternatives for fossil fuels: A review and perspective



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ABSTRACT

Winemaking is a global industry that needs to advance with the times taking into consideration the developing drinking needs, tastes of human beings and the growing demand on the world's renewable energy sources. Climate changes have brought nowadays challenges of energy requirements, subsequent emissions and the detrimental effects facing the winemaking industry and mankind. Given its energy requirements, concomitant emissions and the pernicious effects, winemaking industry should bear the brunt of improving energy utilization efficiency and promoting the development and adoption of renewable energy utilization technologies. Various kinds of renewable energy are being used in winemaking industry worldwide, especially solar energy in the form of solar thermal and solar photovoltaic, which offer a clean solution to fossil fuels shortage and pollutant emissions caused by or involved in winemaking processes. The objective of this paper to present challenges facing solar energy utilization in winemaking by summarizing the status of solar energy utilization in wineries worldwide, by outlining the current solar energy profile of these wineries and by stressing the existing and potential application aspects of solar energy in winemaking. Considering the more rapid development of PV industry, PV chain and economic feasibility are analyzed. By taking China as an example, the comparison and asymmetry between PV production and active solar-related winemaking are stressed aimed at appealing to winemakers and policymakers to turn more to renewable energy like solar energy. Based on that, essential suggestions are provided, which are expected to extend solar energy systems for subsequent contributions to energy conversation, environmental protection and reduction of land occupation.

1. Introduction

Recent decades have witnessed a growth of wine production and consumption worldwide due to the development of manufacturing techniques and increasing living standards. The estimated global wine production is 278.6 Mhl^a in 2013 according to the International Organization of Vine and Wine (OIV) [1], with Europe accounting for the largest portion of 59% (hl here means hectoliter, a unit of measurement commonly used in wine, and 1 Mhl = 1 × 10⁶ hl.) [2]. In California, the estimated consumption of electricity per year by over 1100 wineries which produce over 500 million gallons of wine per year is up to 400 GWh, with considerable amounts of fuel including natural gas, LPG and propane supplementing [3], not to mention electricity consumption of wineries worldwide. The huge energy consumption and enormous wine production inevitably aggravate the stress on environmental protection by serious emissions of greenhouse gas and/or harmful air and large amount of winery wastewater/residues (a winery produces 1.3–1.5 kg residues per liter of wine produced and 75% is

winery wastewater [4]) discharge. Furthermore, the low efficiency in existing energy utilization has brought about severe resource waste and environmental pollution. With ever-going efforts on emissions reduction, resource conservation and energy efficient utilization, renewable energy utilization technologies are getting more significant in global energy and environmental issues, thus spontaneously promoting cleaner production in winemaking industry. Among the renewable energy technologies, solar energy technologies, i.e. solar thermal and solar photovoltaic, are more and more widely adopted in winemaking industry due to their irreplaceable advantages in fossil fuels saving, emissions reduction, cleaner production and energy storage.

The most important drivers of sustainability initiatives in wine-making industry are the environmental values, personal preferences and satisfaction with this profession [5]. With the development of active solar energy in winemaking industry, the concept of 'solar winery' has been attached more importance to. The general definition of 'solar winery' requires the buildings and processes directly or indirectly utilizing solar energy technically collected by the solar collectors mounted

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Nomenclature and acronyms			
PV	photovoltaics	SA-WSHP	solar assisted water source heat pump
OIV	international organization of vine and wine	IX-SAHP	indirect expansion solar assisted heat pump
PAR	photosynthetically active radiation	AOP	advanced oxidation process
LPG	liquefied petroleum gas	COP	coefficient of performance
PV/T	photovoltaic/thermal	CHCP	combined heat, cold and power
WWW	winery wastewater	CPC	compound parabolic collector
STC	solar thermal collectors	COD	chemical oxygen demand
AC	alternating current	DOC	dissolved organic carbon
DHW	domestic hot water	TOC	total organic carbon
DC	direct current	BOD	biological oxygen demand
STS	solar thermal system	GHG	greenhouse gas
R&D	research and development	CFL	compact fluorescent lamps
SHWS	solar hot water system	RO	reverse osmosis
SESS	solar energy storage system	UV	ultraviolet
SAHP	solar assisted heat pump	SPEF	solar photoelectron-Fenton
DX-SAHP	direct expansion solar assisted heat pump	IBR	immobilized biomass reactor
SA-ASHP	solar assisted air source heat pump	MBR	membrane bioreactor
		SES	solar energy system
		PAR	photosynthetically active radiation

on the ground or the roof of the vineyard or winery [6]. As a matter of fact, solar energy plays a quite important role in producing materials (grapes) for winemaking processes. Beyond that, a majority of winemaking buildings or processes are utilizing solar energy in the form of heat gain or daylight to a smaller or larger extent. Stand-alone small-scale equipment powered by solar energy has been utilized in wineries of different scales for years in remote districts. However, large-scale solar energy collectors which can independently cover the energy consumption in wineries is not available although solar energy devices able to supply a proportion of winemaking energy consumption are rapidly developing due to its positive influence on energy usage and carbon footprint.

This paper owns four main parts: energy use in winemaking industry, worldwide distribution of solar wineries, aspects of active solar energy use in winemaking and the related discussions and challenges, which highlights our motivation and objective of summarizing distribution of solar wineries worldwide, presenting the types and modes

of solar installations within these solar wineries, describing the existing and potential application aspects of solar energy in winemaking industry and eventually encouraging relevant wineries to turn more to renewable energy. The abovementioned summaries, PV value chain and economic feasibility analysis reveals the fact that the geographic location of photovoltaic production and winemaking development are not always overlapping with China being a case study. In addition, essential suggestions aimed at are extending solar energy installations for subsequent contributions to reduction of emissions and land occupation, energy conservation and environmental protection.

2. Energy use in winemaking industry

2.1. Energy flows

Winemaking is a global industry consisting of different links from gradients production in vineyards to winemaking processes in wineries

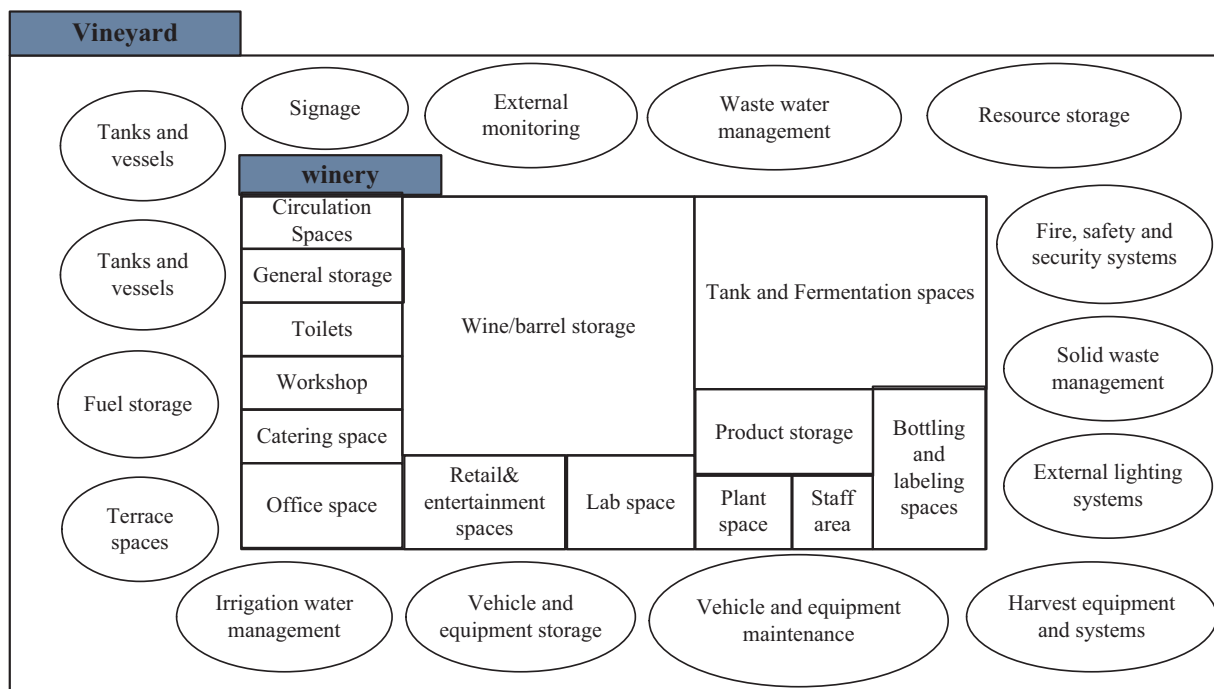


Fig. 1. Schematic show of winemaking requirements [7].

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