# ABSTRACT

Since the gains associated with solar thermal energy technologies are comparatively small in relation to the required capital investment, it is vital to maximize conversion efficiency. While providing the necessary function of freeze protection, the heat exchanger commonly included in solar domestic water heating systems represents a system inefficiency. There is either a significant energy loss due to a rise in collector operating temperature and subsequent decrease in collector efficiency or a significant return on investment loss due to the requirement of a very large heat exchanger. This thesis explores two alternate methods of providing freeze protection without resorting to a heat exchanger.

Commonly, collectors are made of rigid copper tubes separated by copper or aluminum fins. Cracking damage can occur when water is allowed to freeze and expand inside the non compliant tubes. The possibility of making collectors out of an elastic material was investigated and shown to be effective. Since unlike copper, elastomers typically have low thermal conductivities, the standard collector performance prediction equations do not apply. Modified thermal performance prediction equations were developed which can be used for both low and high thermal conductivity materials to provide accurate predictions within a limited range of plate geometries. An elastomeric collector plate was then designed and shown to have comparable performance to a copper plate collector whose aperture area is approximately 33% smaller.

Another option for providing freeze protection to an SDHW system is to turn it off during the winter. Choosing a three-season operating period means two things. First, the system will have different optimums such as slope and collector area. Second, the wintertime solar energy incident on the collector is unavailable for meeting a heating load. However, the system's heat exchanger becomes unnecessary and removing it increases the amount of energy that arrives at the storage tank during those periods in which the system is operating. Both economic and thermal performance predictions were made for a number of locations across the United States, which show that the three-season system is a viable alternative in some locations. In most locations the three-season system provides a lower annual solar fraction. In locations along the coasts and specifically in the southeastern United States, the three-season system actually has a higher solar fraction than the four-season system. In mountainous regions the thermal penalty associated with the three-season system makes it an undesirable alternative. Furthermore, comparatively small penalties are associated with smaller system sizes. The economic analysis of three-season systems showed that they are no more sensitive to economic parameter or design changes than the four-season system.

Because the solar fraction is decreased in most locations by shutting an SDHW system down for the winter, it is beneficial to make the "winter" as short as possible by taking measures to prevent the collector from freezing. During the first and last month of winter, it was found that for most locations, the amount of energy that can be collected during daylight hours is significantly more than is lost if hot tank water is circulated through the collector during the night to prevent freezing. Such a control strategy is inexpensive to implement and significantly improves the solar fraction of the three-season system.

As a final step to the analysis, the three-season system ensemble impact on an electric utility was studied. The utility benefits during peak demand times because the SDHW system ensemble meets the water heating requirements of the service district. Four-season systems are of benefit to the utility as well but since peak demand occurs during the summer, the three-season system is better adapted to the utility's needs. The Milwaukee, WI utility analyzed can expect a substantial increase in return on investment for a 1000 unit three-season system ensemble as compared to a 1000 unit four-season system ensemble under current economic conditions.