SOLAR WATER HEATING IN QUEENSLAND: THE ROLES OF INNOVATION ATTRIBUTES, ATTITUDES AND INFORMATION IN THE ADOPTION PROCESS.*

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The public acceptance of solar domestic water heaters in Australia is explored with special reference to Queensland. Classical diffusion-of-innovations theory is used as the basis for a telephone survey of over 400 new Queensland householders. Survey results indicate that solar water heaters were readily available for purchase and imply that limited effort needs to be expended on further establishing consumer awareness in the market examined. Householders typically established technical feasibility before serious consideration of the solar option and financial viability before adoption. Friends, neighbours and social networks were very important in communicating relevant information. Survey responses suggest that government agencies and electricity authorities played a limited role in promoting the use of solar water heaters for new housing in Queensland. Some policy implications and promotional measures are discussed.

Keywords: solar water heating, solar acceptance, renewable energy use, energy policy, innovation diffusion, Queensland.

INTRODUCTION

The World Commission on Environment and Development[1], identified several major risks associated with the combustion of fossil fuels. These included climatic change due to the greenhouse effect, urban/industrial air pollution and acidification of the environment. In Holdren's assessment[2], such environmental impacts of non-renewable energy supply are now being seen as "pervasive and persistent liabilities" rather than as local nuisances. Accordingly, attention is being paid to the role of energy efficient and renewable (solar) energy technologies in ameliorating the environmental impacts of non- renewable energy supply and us in Australia.[3]

The technical feasibility of solar domestic water heating was established in Australia largely through the efforts of CSIRO in the two decades from 1957[4] and through more recent support from the Federal Government's National Energy Research, Development and Demonstration Council. Solar water heaters are Australia's most widely

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used active solar energy technology. Nationwide distribution networks have been established since 1980 through the efforts of companies such as Solahart, Edwards, Beasley and Rheem. The most popular system has been the roof-mounted, close-coupled, mains-pressure type with electric booster.[5]

This paper is located in the broad area of consumer behaviour and energy policy, which is based on the premise that successful energy policies emerge from a good understanding of energy consumers.[6] It explores the public acceptance of solar domestic water heating in Australia, with particular reference to a telephone survey of Queensland householders. The survey focuses on householder consideration of, and decision-making in relation to, the choice of water heating options for new homes. Some broad policy strategies for promoting the use of solar water heating are developed.

THE PROBLEM

Most recent figures available from the Australian Bureau of Statistics[7] show that in 1985/86 about 250,000 or five per cent of Australian households used solar water heaters. However, as shown in Table 1, considerable differences in levels of use between individual States are concealed by these aggregate figures. In 1985/86, market penetration varied from a high of 42.5 per cent in the Northern Territory to an insignificant low in Tasmania, with some 5.3 per cent of Queensland households using solar water heating.

Differences in market penetration between States have traditionally been attributed to cost-effectiveness differentials at the State level, resulting from insolation variation and interstate differences in household electricity prices.[8] Lowe, Backhouse and Sheumack[9] showed, however, that survey responses of solar adopters in five States did not strongly support economic determinism and suggested that perceptions of both financial and non-financial issues were important. Diesendorf[10] identified non-technical barriers to the wider use of solar energy. Bradbrooke[11] examined legislative issues and solar energy use. Foster[12] suggested that these dimensions may be usefully considered as part of the overall marketing strategies/public policies matrix. Market penetration depends on consumer awareness, consideration and decision-making, all of which may be shaped by private sector and public sector policies.

Salient private sector policies may relate to distribution, price, product, and advertising of solar water heaters. Pertinent public policy areas[13] may include:

- energy supply policies and institutional arrangements;
- electricity tariff structures and availability;
- solar research and development;
- solar demonstration projects;
- financial incentives for solar system purchase;

- public information and education on solar technologies;
- consumer protection (e.g., solar access laws); and
- financial concessions for conventional energy sources.

TABLE 1
SOLAR WATER HEATER USE IN AUSTRALIA, 1985/86

State/Territory	Cumulative Sales (,000)	Market Penetration (%)
Northern Territory	10.4	42.5
Western Australia	107.3	24.5
Australian Capital Territory	4.8	6.6
Queensland	40.4	5.3
New South Wales	62.3	3.8
South Australia	15.1	3.4
Victoria	8.3	0.7
Tasmania	—	—
Australia	**248.7**	**5.3**

Note: Single, non-shared systems only included.
Source: Australian Bureau of Statistics, *National Energy Survey: Households, Appliances, Facilities and Insulation, Australia, 1985/86,* Central Office, Canberra, 1988, p.15.

Comprehensively assessing the likely impact of various policies on solar water heater use is contingent on a better understanding of energy consumer behaviour. This understanding may be derived from previous consumer literature, especially classical diffusion model theory, and empirical householder surveys. Surveys at the State level are particularly appropriate given that energy policy in Australia has been traditionally a State matter. Recent studies into solar water heating acceptance have been completed in Victoria, Western Australia and South Australia.[14] The present survey focuses on Queensland, the Sunshine State, and draws on classical diffusion-of-innovations theory.

DIFFUSION THEORY

A considerable body of consumer behaviour and marketing literature has examined the diffusion (or spread) of technological innovations (new consumer durables). Kelly and Kranzberg[15] identify three major diffusion research traditions — the social/psychological, economic and geographical — with each being characterised by a distinctive conceptual structure. The social/psychological diffusion model, also called the classical diffusion model, dominates and is of most interest here. The model is based on a synthesis of some 2,400 diffusion research publications carried out by Rogers and Shoemaker;[16] it is refined and updated in Rogers.[17] The classical diffusion model has provided the theoretical base for many solar adoption studies in the USA.[18]

Underpinning the classical diffusion approach is general agreement on the importance of social context and networks.[19] Diffusion is seen

as a social process involving adopters and others who are profoundly influenced by cultural setting, social norms and government institutions. Emphasis has been on four key elements of the diffusion process: (1) an innovation, (2) communicated via certain channels, (3) to members of a social system, (4) who adopt or reject it over a period of time.[20]

According to Rogers,[21] five main attributes of innovations influence acceptance behaviour. These are relative advantage, compatibility, complexity, trialability and observability. Bauer suggested that risk is also an important innovation attribute[22] and this dimension has been evaluated in many diffusion studies. Risk is the expected probability of economic or non-economic problems resulting from innovation adoption. Relative advantage is the degree to which an innovation is seen as superior to prior innovations fulfilling the same needs. Compatibility is the degree to which an innovation appears consistent with existing values, past experiences and needs of the potential adopter. Complexity is the degree to which an innovation appears difficult to understand and use. Trialability is the perceived degree to which an innovation may be tried on a limited basis. Observability is the perceived degree to which the results of innovating are visible to others. Relative advantage, compatibility, trialability, and observability are positively related to adoption while risk and complexity are negatively related.[23]

THE QUEENSLAND SETTING

Australia's largest solar water heater supplier, Solahart, began Queensland distribution in 1975. Queensland was the second state tackled after Western Australia.[24] A Queensland sales manager was appointed in 1985 when a State office opened to co-ordinate Queensland operations.

Queensland has very large deposits of high quality coal and the public sector has placed considerable emphasis on building coal-fired power stations. During the 1980s statutory electricity authorities actively promoted increased electricity consumption. In 1985, newspaper advertisements promoting the use of electricity were common. Widespread, multi-media promotion of electricity industry rebates for the consumer purchase of off-peak water heaters and air conditioners began in 1986. 1987 saw nationwide advertising designed to attract electricity-intensive industry to Queensland.[25]

Solar suppliers have consistently reported that off-peak electric water heater promotions reduce solar water heater sales. "All- electric" housing estates also acted to curtail the domestic use of solar energy and gas in the 1980s. Since 1985, several solar vendors either closed their business or diversified into other energy products.[26] Production of the award-winning, Queensland-designed, solar tracking water heater ceased in 1989.[27] Table 2 shows historical sales trends for solar water heaters in Queensland.

SURVEY DESIGN AND SAMPLE PROFILE

The new housing market is the focus of the present study for three main reasons. First, because it represents an important market segment and, secondly, because solar water heaters may be installed more economically in new homes. The third reason is that the recall problems of retrospective surveys, identified by Rogers[28], are ameliorated. A point-of-decision approach has been used where respondents were asked for information about adoption and rejection very soon after they actually made the decision. This approach could be expected to enhance data quality and response rate.

Seven local government areas having high levels of housing approvals in 1988/89 were surveyed, in similar proportion to actual housing approval numbers in each area, as part of a larger study.[29] These areas ranged from northern coastal Queensland to the south-east corner of the State. The target population was householders who had received Council approval to build a new detached dwelling but were yet to take up occupancy. Telephone interviews were conducted during 1990 using

TABLE 2
SOLAR DOMESTIC WATER HEATERS IN QUEENSLAND, MARKET TRENDS

Year	Cumulative Sales	Market Penetration (%)
1976[a]	—	0.4
1980[b]	17,600	2.6
1983[c]	30,400	4.1
1985/86[d]	40,400	5.3

Sources: [a]Australian Bureau of Statistics, *Australian Census 1976,* Central Office, 1977; [b]Australian Bureau of Statistics, *National Energy Survey November 1980,* Central Office, p.5; [c]Australian Bureau of Statistics, *National Energy Survey June 1983,* Central Office, pp.9-10; [d]Australian Bureau of Statistics, *National Energy Survey 1985/86,* p.15.

names and telephone numbers obtained from recent housing approval lists. Responses were obtained from the household member who played the major (or an equal role) in making decisions about the new house. Four hundred and fifty-two interviews where completed, representing an effective response rate of 78 per cent. Fewer than eight per cent of those contacted refused to be interviewed.

Most respondents (70%) did not have a diploma or degree. There were more males (54%) than females (46%) in the sample and a majority of respondents (66%) were in the 30 to 49 age group. A wide range of occupations, particularly trades and professions, were represented. Eighty-five per cent of respondents reported sympathy with the environmental movement.

In terms of housing characteristics, almost one-third of building approval files inspected related to owner-built homes. A plethora of small

building firms were involved in constructing the remaining houses. Houses were mainly in the $50,000-70,000 price range, on a 700-1200 square metre block, having a floor area between 150 and 200 square metres, with concrete slab-on-ground construction. The majority were low set and rectangular in shape.

SOLAR ACCEPTANCE SURVEY RESULTS

Some 5 per cent of respondents had no choice about the type of water heater to be installed in their new home, either because the builder made this decision or because the house was located in an "all- electric" housing estate. A further 5 per cent had considered solar and other water heating options but had not made a purchase decision at time of survey. A handful of respondents had not considered any water heating options. Each of these groups of respondents are excluded from Tables 3 to 7. Ten respondents who considered non-solar water heating options but had not made a purchase decision at the time of survey are excluded from Table 3 only.

Table 3 shows that many respondents considered more than one water heating option. Electric (especially off-peak) water heating was particularly popular. Some 55 per cent of respondents had not seriously considered the solar alternative. About seventy per cent of respondents who considered solar decided against installation. Respondents were categorised into three basic groups: 53 "adopters" who installed (or intended to install) a solar water heater, 122 "rejecters" who considered solar but ultimately rejected it and 225 "non-considerers" who did not consider the solar option.

TABLE 3
HOT WATER SYSTEM OPTIONS

Type	Consideration	Decision	Rejection Rate
Electric	341	269	21%
Solar	175	53	70%
Gas	116	68	41%

Factors affecting consideration of, and decisions about, solar water heating were many and varied; only more common responses are discussed here. Adopters were motivated by both financial and non-financial factors, especially power bill reductions, energy conservation and previous solar ownership. Rejecters overwhelmingly saw the relatively high capital cost as the main barrier to adoption although a significant number felt that solar water heating would not be cost effective over the system lifetime. In the case of non-considerers these financial problems precluded serious consideration of the solar option. Some non-financial issues were of lesser importance for both rejecters and non-considerers, as Table 4 shows.

TABLE 4
FACTORS INFLUENCING HOUSEHOLDER GROUPS

Householder Group	Most Important Factors	% of Respondents in each group	% of Responses in each group
ADOPTERS (n=53)	Power bill reductions	74	37
	Energy/fossil fuel conservation	42	21
	Previous ownership/use	25	12
	Reduced maintenance costs	17	8
	Friend/builder recommended it	11	6
REJECTERS (n=122)	Higher initial cost	70	42
	Not cost effective	25	15
	Limited hot water/need booster	22	13
	Bad reports/experience	16	10
	Aesthetics/ugly on roof	10	6
NON-CONSIDERERS (n=218)	Higher initial cost	62	38
	Not cost effective	28	17
	Aesthetics/ugly on roof	15	9
	Bad reports/experience	12	7
	Stick to known system	10	6

Householder Attitudes

Householder responses to a series of 21 attitude statements about solar hot water systems were obtained using a six-point Likert scale. The statements, drawn partly from Guagnano *et al.*,[30] covered technical, financial, environmental and social issues. Analysis mainly involved calculating a mean score based on the first five points of the scale running from 1 (strongly agree) to 5 (strongly disagree). The sixth point of the scale, "Don't know", did not enter into this calculation. On this basis, the sample as a whole strongly agreed that solar water heating was appropriate for their climate and saved fossil fuels. Selected items and results highlighting differences between groups are presented in Table 5 for adopters, rejecters and non-considerers.

As expected, adopters generally had a more favourable disposition to solar than rejecters who, in turn, had a more favourable disposition than non-considerers. The mean score of non-considerers and rejecters was usually closer than rejecters and adopters. The attitudinal difference between adopters and rejecters was particularly marked for financial issues. Compared with rejecters, adopters found the capital cost issue to be less problematic and assessed solar to be a much better investment proposition. Attitudes distinguishing non-considerers and rejecters were mainly technical. Compared with rejecters, non-considerers perceived more problems with early obsolescence, the unproven nature of the technology and explaining the operation of a solar water heater. These trends suggest that householders established technical understanding and/or feasibility before serious consideration of the solar option and established financial viability before adoption.

TABLE 5
SELECTED HOUSEHOLDER ATTITUDES

Attitude Statement (n=400)	Mean Score			Don't Know
	Non-cons.	Rejecters	Adopters	
Likely to become obsolete quickly^{++}	3.8	4.1	4.6	41
Difficult to explain operation^{++}	4.0	4.3	4.7	22
Initial cost too high^{+}	1.4	1.6	2.5	39
Hard to understand how it pays^{+}	3.5	3.6	4.4	15
Good investment for me^{+}	3.4	3.1	1.5	16
Is reliable^{+}	2.6	2.4	1.5	74
Would reduce power bills^{+}	2.3	2.1	1.3	21
Is easy to operate^{++}	1.8	1.6	1.2	65

Note: All statements listed show a significant t-test difference between adopters and non-considerers at the $p=0.0001$ level. Statements with one "+" superscript show a significant t-test difference between adopters and rejecters at the $p < 0.001$ level. Statements with two superscripts also show a significant t-test difference between rejecters and non-considerers at the $p < 0.02$ level.

Social Issues and Information-Processing

All respondents were questioned about their main sources of information on solar water heating; an average of slightly less than two answers per respondent was received. Responses (from more to less frequent) included: friends/neighbours/relatives/associates (referred to subsequently as peer group), home shows/exhibitions/consumer groups, sales representative/equipment suppliers, pamphlets/books, builder/designer, media reports, previous solar ownership/use and unknown/no source.

Table 6 refers to information sources seen as the single most important. Twenty one per cent of non-considerers were unable to name their most important source of information. Rejecters chose their peer group. Adopters cited previous ownership, or use of solar in a rented residence, as the most important source of information on which to base their decision. Previous ownership or use was also an issue for rejecters who ranked it fourth on their list of most important information sources.

Given the importance of peer group contact as an information source, it is unsurprising that there was a strong correlation between a respondent's propensity to adopt and the number of homes (of friends, etc.) known to have a solar water heater. This relationship is illustrated by data in Table 7, which yield a very significant Chi-square correlation as shown, and reinforce the importance of social networks in solar diffusion.

TABLE 6
MOST IMPORTANT INFORMATION SOURCE

Householder Group	Information Source	% of Respondents and Responses in each group
ADOPTERS	Previous ownership/use	21
(n=53)	Sales reps./suppliers	19
	Peer group	13
	Media reports	13
REJECTERS	Peer group	23
(n=122)	Home shows/exhibitions	18
	Builder/designer	11
	Previous ownership/use	10
NON-CON-	Unknown/none	21
SIDERERS	Peer group	20
(n=225)	Sales reps./suppliers	9
	Builder/designer	9

Statistical analysis (using the Chi-square test) and interpretation showed that no significant relationship existed between solar water heating acceptance and traditional socio-economic variables associated with income, occupation and education. This result is primarily attributed to the homogeneous situation of the sample, in that all respondents were in the process of building a new home.

TABLE 7
NUMBER OF HOMES THAT RESPONDENTS KNEW TO BE USING SOLAR WATER HEATING

Number of Homes (n=400)	Group Percentage		
	Non-considerers	Rejecters	Adopters
None	36.0	25.4	11.3
1—2	35.1	34.4	26.4
3—5	11.6	18.0	28.3
6—10	4.4	9.0	15.1
11 and over	4.0	5.7	13.2
Don't know	8.9	7.4	5.7

Note: Chi-square = 32.33, $p < 0.0001$, 10 d.f.

Innovation Attributes

Factor analysis using the Promax rotation,[31] based on responses from 21 Likert scale items, was undertaken for data on perception of solar water heating. As expected, the primary factor matrix yielded simple structure. Results are shown in Table 8 where larger (positive or negative) loadings are, of course, more important in the interpretation of a factor.

TABLE 8
SUMMARY OF FACTOR ANALYSIS RESULTS

Factor No. and Item (n=452)	Factor Loading	Associated innovation attribute
FACTOR ONE (Relative advantage and Compatibility)		
Would reduce power bills	0.76	Relative advantage
Good investment for me	0.71	Relative advantage
Gives house higher value	0.54	Relative advantage
Appropriate for climate	0.45	Compatibility
Improves indoor comfort levels	0.39	Relative advantage
Hard to understand payback	−0.49	Complexity
FACTOR TWO (Complexity and Risk)		
Difficult to approve	0.55	Complexity
Hard to explain operation	0.44	Complexity
Represents unproven technology	0.42	Risk
Likely to become obsolete	0.38	Risk
Is reliable	−0.40	Risk
Is easy to operate	−0.58	Complexity
FACTOR THREE (Trialability and Observability)		
Is an eyesore	0.39	Observability
Difficult to try	0.39	Trialability
Readily visible to others	0.38	Observability

Note: Only items with factor loadings outside the interval between 0.37 and −0.37 are shown.

Factor one may be interpreted as a combination of relative advantage and compatibility. Factor two operationalises the theoretical dimensions of complexity and risk. Factor three is associated with trialability and observability. These results provide support for the existence of the theorised dimensions identified in the diffusion-of-innovations literature, but suggest that the distinction between dimensions is blurred.

The three factors represent a composite of the six hypothesised innovation attributes discussed earlier. Separate factor analyses for solar adopters, rejecters and non-considerers were carried out but this did not assist with interpretation in terms of the hypothesised dimensions. A clearer breakdown of factors may have resulted had more survey items been used to measure the theoretical dimensions and/or if public acceptance of the solar water heating concept had been less. These conditions applied in the confirmatory factor analysis of Guagnano *et al.*.[32]

DISCUSSION

The majority of Queensland householders surveyed considered and made decisions concerning solar water heating and did not simply leave the issue of installation to the discretion of builders or designers. Typically,

householders established technical feasibility before serious consideration of the solar option and financial viability before adoption. Friends, neighbours and local social networks were very important in facilitating the communication of information about solar water heating. From the perspective of survey respondents, mass media, government agencies and electricity authorities played a limited role in promoting solar water heating use. Survey results suggested that solar water heaters were readily available to consumers and that existing product distribution channels were adequate.

Results imply that limited effort needs to be expended on further establishing consumer awareness of solar water heating in the new housing market. However, some effort needs to be put into translating high awareness levels into higher rates of consideration of solar water heating. Discontinuance of the restrictive "all-electric" agreements, between some electricity authorities and real estate developers, will make a positive contribution here.[33]

Demonstration of the technical feasibility of solar water heating is another potentially useful strategy. Such demonstrations would act as a surrogate trial for consumers and could involve small-scale displays as well as use of solar water heating in display homes and government buildings. Both equipment supply companies and public sector agencies could be involved.

Most attention, however, should focus on the large proportion of new householders who considered the solar option but did not follow through. As well as technical feasibility, other issues which need to be tackled in order to comprehensively facilitate the transition from consideration to adoption include capital cost, operating economics, authoritative information and user satisfaction. Each of these issues needs to be considered not so much in an absolute sense, but rather in terms of the relativities between solar and other water heating options. The last two of these issues deserve some explanation.

The user satisfaction issue derives mainly from survey results which show that many previous solar users chose not to use solar in their new home and also from the importance of word-of-mouth communication. While this interpersonal information has generally been positive, steps could be taken to reinforce it. Personal communication channels are especially vulnerable to rumour and horror stories.

In the absence of clear, simple information about actual benefits of water heating alternatives, consumers appear to have relied more heavily on interpersonal sources which they believe are credible. Thus, the virtual absence of authoritative information (especially official publications from government or university sources) has probably contributed to the dominance of interpersonal communication. This gives rise to the authoritative information issue.

There is a wide range of promotional public policy options which may impinge on these key issues. At the Federal level these include increased public participation in energy policy decisions, formation of a National Renewable Energy Institute, a revitalised national renewable energy research and development programme, sales tax adjustments favouring solar, income tax deductions for solar installation, movement towards energy prices that better reflect environmental costs, an unequivocal commitment to climate stabilisation and ecologically sustainable development, as well as improved product standards and testing. These are all important areas and several are beginning to receive attention.[34]

Since the time of the survey reported in this paper, Queensland Government instrumentalities have given some attention to the potential role of solar water heating in Queensland. A public Energy Information Centre has been established, and conceivably could take a pro-active role with respect to solar water heating. A 1991 Queensland Government energy policy discussion paper[35] canvassed a number of the public sector options for promoting the use of energy alternatives. Major electricity distribution authorities have been seen to be "more receptive to the solar industry" in recent years.[36] A range of public sector policy options which may be implemented at the State or Local Government level are listed in Table 9 and linked to the five key issues identified above. Many of these policy options have precedents set outside Queensland.

TABLE 9
A TAXONOMY OF POLICY OPTIONS FOR PROMOTING SOLAR WATER HEATING IN QUEENSLAND

Issue	Public Policy Options
TECHNICAL FEASIBILITY	Demonstrations Displays
CAPITAL COST	Financial incentives State Government procurement Local Government procurement
OPERATING ECONOMICS	Electricity tariff reform Institutional rearrangements
AUTHORITATIVE INFORMATION	Solar information brochure/s Energy education centre/s Power industry endorsement Solar hotline Regional energy information centres
USER SATISFACTION	Solar access legislation

Financial incentives (e.g., low interest loans, government-guaranteed loans, or targeted rebates) for solar water heating, for example, have been widely used in the USA and were available in the Northern Territory in the early 1980s. The routine government purchase of solar water heaters began in the Northern Territory in 1959.[37] Both of these

measures acted to reduce the capital cost barrier and have contributed to the high solar market penetration levels in the Northern Territory, discussed earlier. In designing a subsidy strategy for Queensland consideration would need to be given to dealing appropriately with low income groups, on the one hand, and "free riders" who would have adopted solar without assistance, on the other. Removal of purchase rebates for traditional water heating methods could be an alternative or complementary strategy.

Queensland Government instrumentalities have been slow to produce a public information brochure dealing exclusively and explicitly with solar water heating. The Victorian Government, in contrast, has devoted considerable effort to producing authoritative solar water heating information brochures and educating consumers through an Energy Information Centre, Energy Education Centre and a Renewable Energy Authority.[38] The State Electricity Commission of Victoria has endorsed the use of solar-electric water heaters, though media advertising, and has received telephone enquiries via a "Solar Hot Water Hotline".[39]

Investigations into domestic sector electricity tariff reform have been reported on in Victoria and several other States. These initiatives involve the use of lifeline, flat-rate, or time-of-use domestic electricity tariff structures in parallel with, or instead of, the traditional declining-block structure.[40] Media promotion of off-peak electricity use has ceased in Victoria and this has been seen to boost the solar water heating industry.[41]

These types of initiatives are, on the basis of survey results, likely to boost solar water heating sales in Queensland. However, the complex relationships between information and attitudes revealed by the survey indicate that no single promotional strategy is likely to be sufficient. Several mutually supporting and complementary strategies should be combined, ideally as part of a coherent energy policy, to enhance effectiveness. With respect to detailed design, field experiments could be used to test and refine specific mechanisms.

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