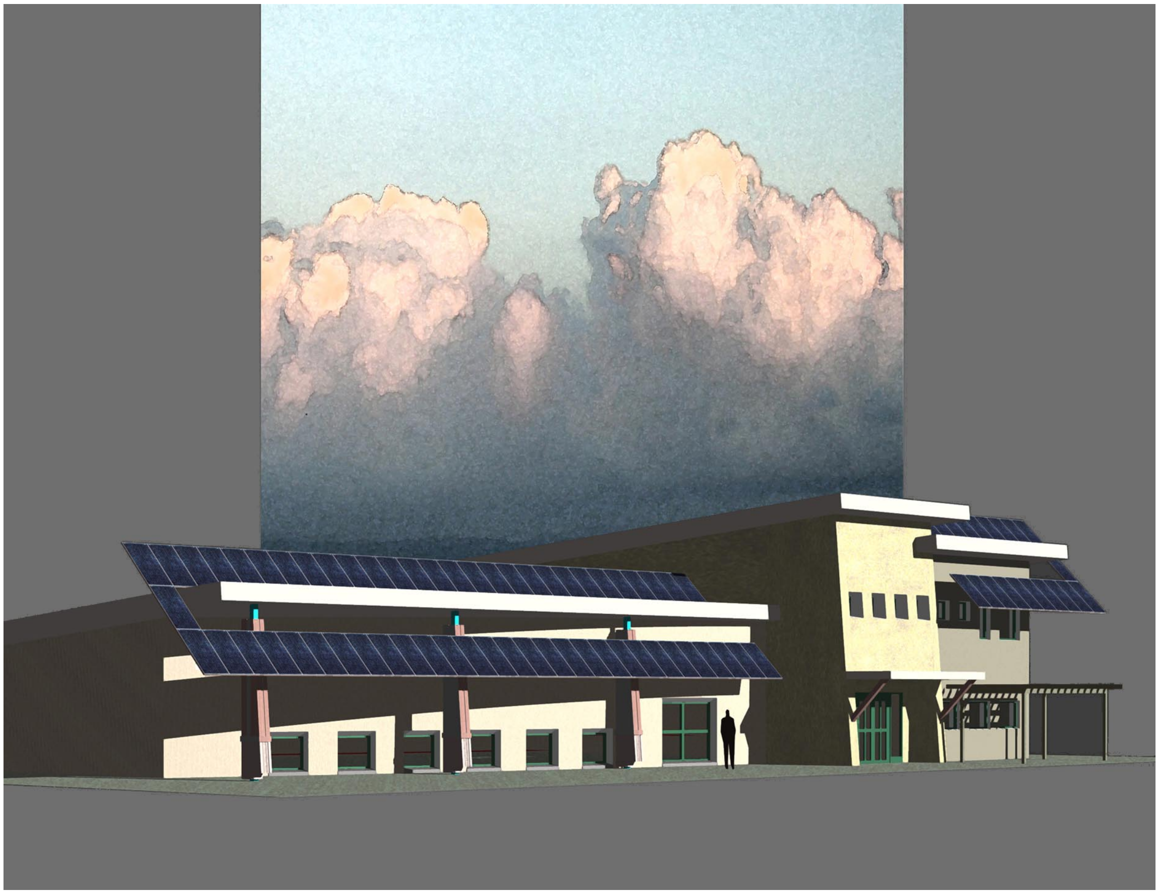
DIRK & TAMI ELLIS
NATURAL FOOD STORE
ROADRUNNER DRIVE ■ HELENA, MONTANA
ENVIRONMENTAL RESPONSE RECOMMENDATIONS
DECEMBER 10, 2003



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INTENT

The owners, having successfully shepherded this project through design development and construction document phases, elected to revisit one specific issue — mechanical heating and cooling systems — and to explore other environmental responses that would complement a forward-thinking design. The baled-straw system sets this design apart from the ordinary and deserved, they believed, the integration of additional systems that would reflect the original design intent and enhance building performance.

The benefit of baled-straw construction lies in the system's efficacy vis-à-vis long-term solutions to excessive carbon release and energy embodied by manufacturing processes now understood to be wasteful even outside the context of depleted resources. The baled-straw system is characterized by simplicity, sourcing reliability, and ease of placement. In place, the system serves exceptionally well as an insulator and fire shield. It has long set the standard for simple reliance on natural processes and long-term architectural solutions. Accordingly, any associated systems should reflect those virtues.

It was also considered paramount to recommend enhancements to what the owners (and consultant) consider a thoughtful architectural response to their needs as environmentally conscious entrepreneurs without resorting to any significant alteration to structure or form. And the enhancements needed to make economic sense.

SUMMARY RECOMMENDATIONS

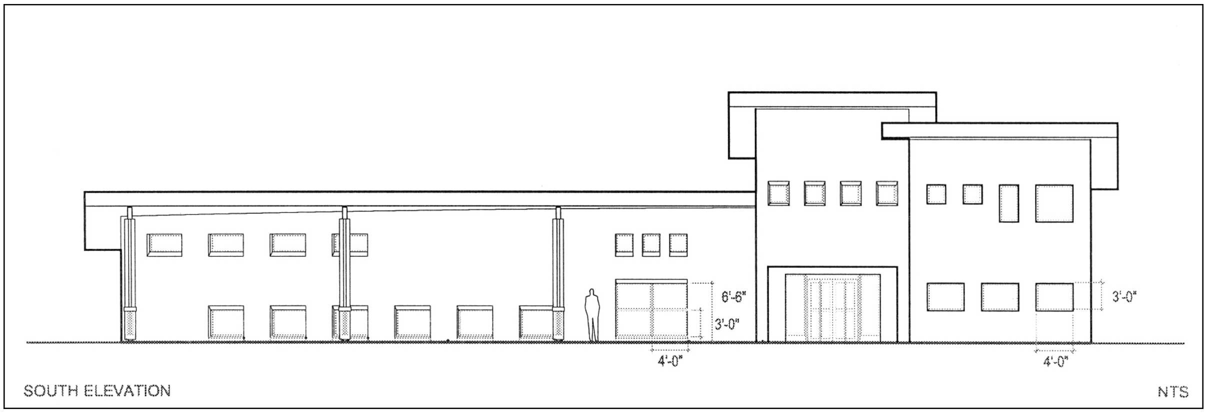
1. Passive solar gain: reconfiguring fenestration at the south elevation to admit and retain solar heat to the interior; downsizing fenestration elsewhere to inhibit heat loss.
2. Cleaner grid-tied photovoltaic power generation to offset utility supplied electricity
3. Ground source heat pump technology for heating and cooling
4. Reconfiguring the site water management to take advantage of incident rain and snow

Rationale for each of these systems is found in the sections following. Generally, each brings to the existing design an economically and environmentally sound enhancement which, considered in tandem with the design, significantly compounds the positive implications of this project. All together, they should produce a building emblematic of the best architectural response to place and climate and a future held in common.

TABLE OF CONTENTS

Each section includes appended case studies and/or product literature.

SECTION I: PASSIVE GAIN AT SOUTH WALL



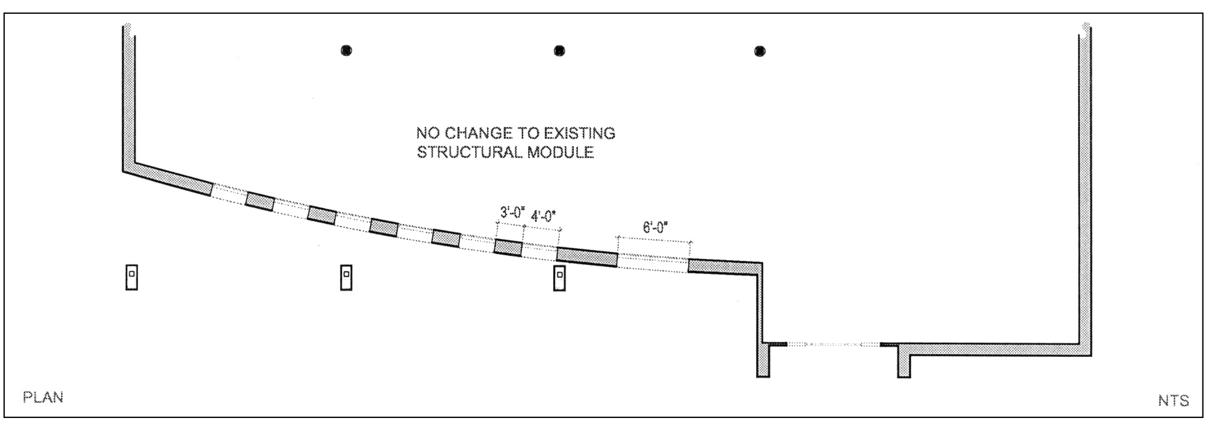
Solar gain for south-facing walls is indicated in practically any Temperate Zone location. The effect is to moderate psychrometric (perceived comfort) requirements and Btu inputs, both of which reduce operating energy needs. It is important to control gain to eliminate potential glare and, in this case, direct sunlight on merchandise and equipment. It is also essential to accomplish any gain without modification to the existing structural scheme.

Simple gain through south-facing windows in Helena's climate exceeds loss through those windows at a ratio of ± 2:1 (with no allowance for Low-E). The object here is to enhance the conduction of solar heat to interior air with absorption in the mass of the slab, thereby delaying total conduction in favor of "timed release" across late afternoon and evening periods.

The recommended scheme increases total fenestration in the affected area of the south elevation by 65% (100 s.f. < 165 s.f.). As shown, 3 windows at south coffee shop booths are reduced to 4030 units to reduce glare. Heat loss from east facing windows far exceeds heat gain. If the total fenestration at the east elevation is reduced (especially at second floor Unfinished Storage) it is possible to affect total potential gain with less total building fenestration than originally proposed.

RECOMMENDATIONS:

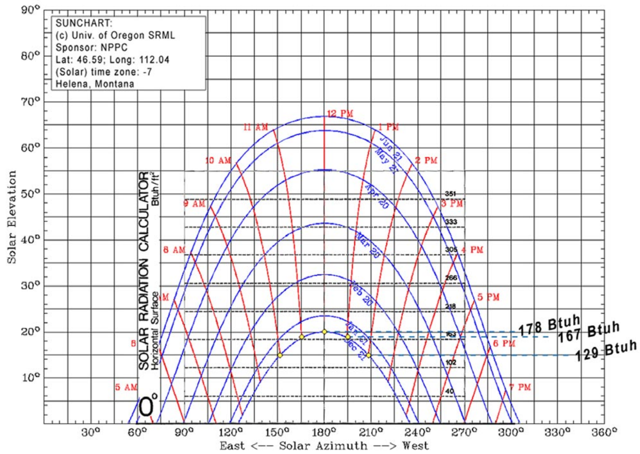
1. Design for 8 ea. 4030 double-glazed / high solar gain Low-E window units @ 6" AFF; nighttime screening to inhibit heat radiation to nighttime sky
2. 2 ea. 4030 double-glazed (high solar gain optional) site-line window units above 2 easternmost high gain units; sheer screening necessary October through February
3. Omit 3 clerestory 4020 window units; remaining 4 to be obscure glass for light diffusion
4. 6" sills to be precast concrete stained darker for immediate exterior gain and daytime conduction at exterior of gain windows; insulated from interior slab
5. Reduce fenestration @ south-facing Coffee Shop and east elevation; consider reducing 2 easternmost south-facing windows @ second floor Unfinished Storage; obscure (diffusing) glass @ all Unfinished Storage windows and @ clerestories other than Office



SOLAR GAIN CALCULATION

December 21 gain totals can be used to estimate worst-case heating requirements for the purposes of sizing Ground-Source Heat Pump equipment. Seasonal totals are shown to suggest the magnitude of annual energy savings. Gain is calculated for the windows indicated in the top right frame.

Per square foot insolation for December 21 at 46.59°N:



Modeling and calculations assume 15° Solar altitude / ±152° azimuth to account for skyline and terrain obstructions.

Solar Radiation intercepted by Horizontal Slab @ 46.59°N:

December 21:

LOCAL TIME	SOLAR TIME	SF	BTUH GAIN/SF	TOTAL BTU GAIN/DAY
11:27	10:00	160	129	20,640
12:27	11:00	173	167	28,891
13:27	12:00	188	178	33,464
14:27	13:00	204	167	34,068
15:27	14:00	240	129	30,960

Total Btus / December 21 148,023

Adjusted @ ASHRAE Clearness Factor (104) 153,944

Adjusted @ 71% for Low-E transmission 109,300

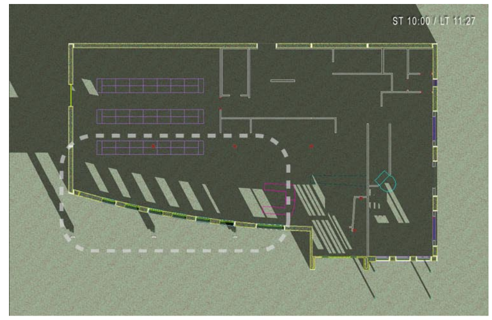
Seasonal (120 days) Total Btus gained 3,333,656

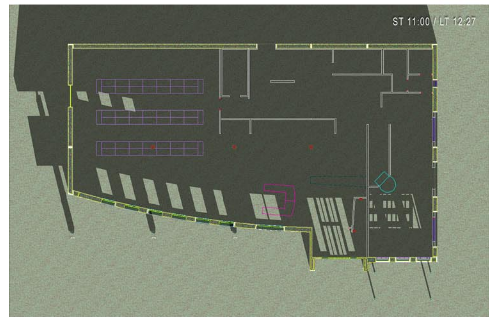
RULE OF THUMB

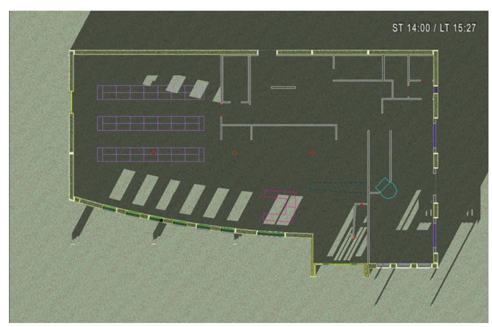
"In cold climates (average temperatures 20° to 30° F), provide between 0.19 and 0.38 square feet of south-facing glass for each one square foot of space floor area…This amount of glazing will admit enough sunlight to keep the space at an average temperature of 65° to 70° during much of the winter."

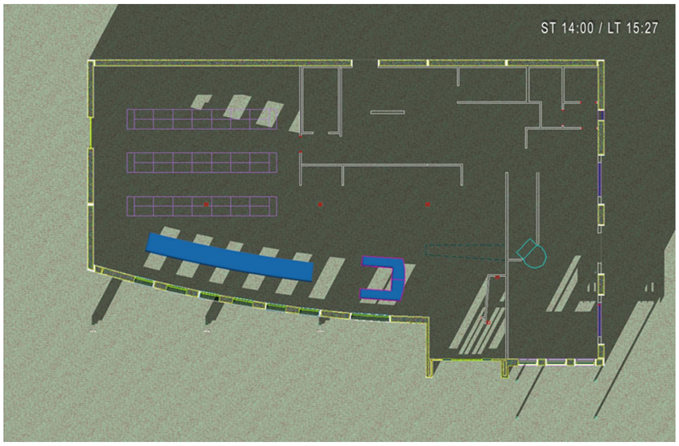
(Edward Mazria, *The Passive Solar Energy Book*, p. 119)

If the space square footage is calculated at 2,900 for Retail Space and the 0.19 recommendation is applied, the solar gain suggested here will meet 19.6% of the total requirement for heat for that space.



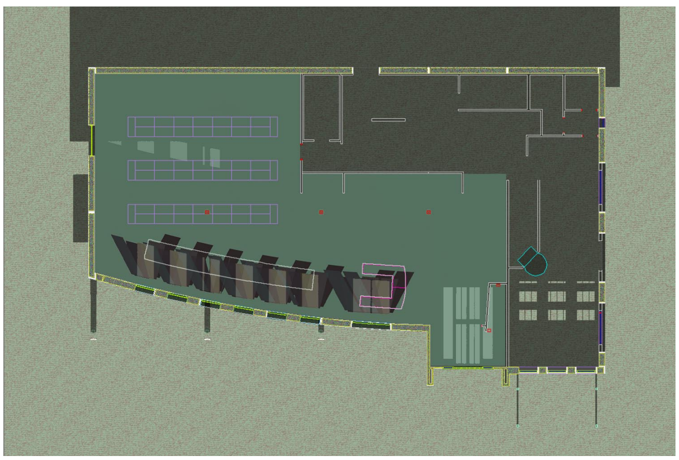






GLARE & DIRECT SUNLIGHT

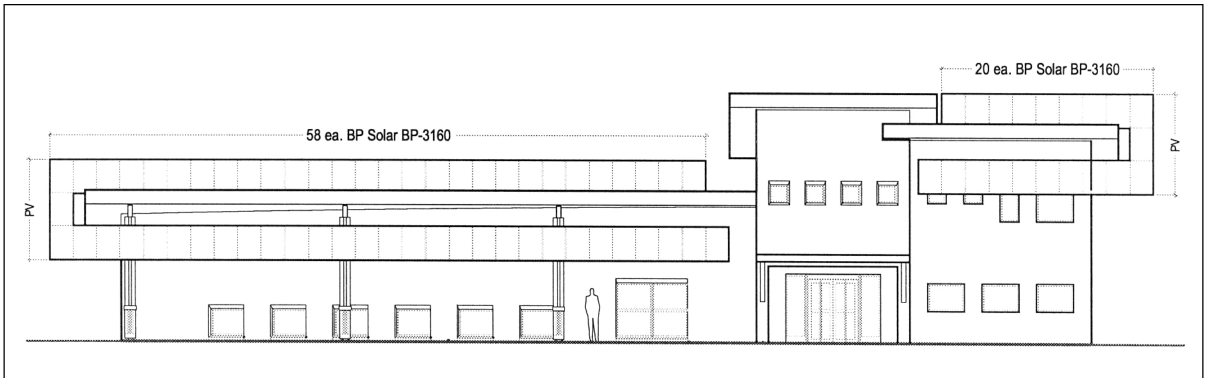
Light reaches farthest into the space (to the highest plane horizontally) at the sun's lowest altitude. In this case the arc of the wall has the positive affect of accentuating the reach in the afternoon. It is possible to avoid direct sunlight on work surfaces and stock shelves. This illustration shows the Check-out Counter surface at 36" above finish floor. At no time during the day does direct sunlight fall on the counter (assuming the sheer shades on the sight-line windows above the solar gain windows are in place). The lowest stock shelf avoids sunlight at 20" AFF.



PATTERNS

This illustration demonstrates but one of the possibilities for adapting the gain pattern to surface treatment. It also points up both the fact that darker pigments enhance the absorption of heat by the concrete slab (for delayed release) and the fact that it is unnecessary to employ such pigments beyond the area of direct insolation in order for the gain scheme to work effectively.

SECTION II: GRID-TIED PHOTOVOLTAIC POWER GENERATION



SOUTH ELEVATION

The era of cheap power draws to a close as natural resources are depleted and the environmental costs of extraction deepen. The difficulty of balancing costs with income increases as each month passes. Accordingly, capital plays a larger role now for those with access. Improved alternatives to conventional fossil-fuel conversion of energy offer broader possibilities for conservation of both natural resources and income.

Conventional generation squanders energy resources. (As much as 90% is lost as heat by the time the light bulb filament glows.) Newer technologies and improved manufacturing processes reducing embodied energy bring environmental payback (in the case of photovoltaics) to a matter of three to five years when balanced against improved efficiencies in power generation. Buying one's own generation facility and enjoying lower unit costs stabilized for the life of the facility is feasible now to a point beyond which much reduced environmental cost becomes merely one positive side effect.

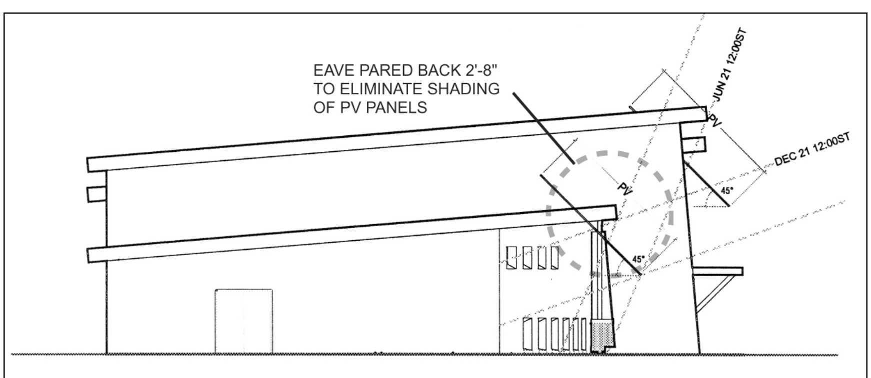
Grid-tied PV arrays offer two benefits over stand-alone systems: reduced capital outlay (no battery necessary), and, in the presence of Montana net-metering law, the ability to abate consumption at full consumer rates at those times when site generation exceeds consumption.

In the absence of connected load totals, a target of 3 kW per month consumed was assumed. That notwithstanding, the building design will support in an architecturally responsible way approximately 12.5 kW (rated power) for an abatement of some 55% of the target.

The application shown here represents the end result of several exercises exploring the possibilities for the maximum PV array possible given the lower sun angles at 46.6°N and the architecture as designed. Although it does not exhaust the total potential, it does maximize power generation as an *integrated* component and derives secondary value as awnings for pedestrian ways and second story south-facing windows.

RECOMMENDATIONS:

1. Design for a minimum 12.5 kW grid-tied photovoltaic array (78 BP Solar BP 3160 panels)



WEST ELEVATION

The following table shows power generation calculations for this array at the tilt, azimuth, latitude, and climate specified.

PVWatts

AC ENERGY AND COST SAVINGS

NATURAL FOOD STORE

STATION IDENTIFICATION

City: Helena, MT

Latitude: 46.60 ° N
Longitude: 112.00 ° W
Elevation: 1188 m

PV SYSTEM SPECIFICATIONS

AC Rating: 12.5 kW
Array Type: Fixed Tilt
Array Tilt : 45.0 °
Array Azimuth: 180.0 °

ENERGY SPECIFICATIONS

Cost of Electricity: 7.5 ¢ kWh

ENERGY PRODUCTION

Month	kWh	Value($)
1	1090	81.75
2	1262	94.65
3	1922	144.15
4	1796	134.70
5	1941	145.58
6	1918	143.85
7	2264	169.80
8	2104	157.80
9	1864	139.80
10	1637	122.78
11	1168	87.60
12	955	71.62
Year	19,919	1,493.92

INTERPRETING THE RESULTS

The monthly and yearly energy production are modeled using the PV system parameters you selected and weather data that are typical or representative of long-term averages during the 1961-1990 time frame. Because weather patterns vary from year-to-year, the values in the tables are better indicators of long-term performance than performance for a particular month or year.

PV performance is largely proportional to the amount of solar radiation received, which may vary from the long-term average by 30% for monthly values and 10% for yearly values. How the solar radiation might vary for your location may be evaluated by examining the tables in the *Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors* (*http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/*).

For these variations and the uncertainties associated with the weather data and the model used to model the PV performance, future months and years may be encountered where the actual PV performance is less than or greater than the values shown in the table. The variations may be as much as 40% for individual months and up to 20% for individual years. Compared to long-term performance over many years, the values in the table are accurate to within 10% to 12%.

The values in the table assume that the PV array has an unobstructed view of the sky. If trees, buildings, mountains, or other obstacles block the sun, the values in the table should be reduced.

The PV system size is an AC rating for Standard Reporting Conditions (SRC). The energy production values in the table are valid only for crystalline silicon PV systems rated at SRC.

The cost savings are determined as the product of the number of kilowatt hours (kWh) and the cost of electricity per kWh. These cost savings occur if the owner uses all the electricity produced by the PV system, or if the owner has a net-metering agreement with the utility. With net-metering, the utility bills the owner for the net electricity consumed. When electricity flows from the utility to the owner, the meter spins forward. When electricity flows from the PV system to the utility, the meter spins backwards.

If net-metering isn’t available and the PV system sends surplus electricity to the utility grid, the utility generally buys the electricity from the owner at a lower price than the owner pays the utility for electricity. In this case, the cost savings shown in the table should be reduced.

Besides the cost savings shown in the table, other benefits of PV systems include greater energy independence and a reduction in fossil fuel usage and air pollution. For commercial customers, additional cost savings may come from reducing demand charges. Homeowners can often include the cost of the PV system in their home mortgage as a way of accommodating the PV system’s initial cost.

PV SYSTEM COST BENEFIT CALCULATIONS

Although the PV rate per kWh is $0.008 higher than the prevailing utility rate, it is locked in for the 30-year design life of the system.

System Rated kW (78 BP 3160)	12.48	
Sun-hours / day	4.25	*One source rates Helena at 5 Sun-hours per day. Two sources rate the region at 4.25 < 4.5.*
kWh's / day	53.04	
kWh's / year	19,360	
kWh's required / year	36,000	
Installation cost per kW	$5,500.00	*Larger arrays (10kW and above) enjoy the economy of scale.*
Overall system cost	$68,640.00	
Tax Credits: % of System Cost	35%	
Less Montana tax credits	($24,024.00)	
Maintenance @ %: Design Life	5%	*Panel life is anticipated to exceed 30 years.*
Maintenance: Design Life	$3,432.00	
Total expenditure	$48,048.00	
Loan amount	$44,616.00	
Interest rate (annual)	7.00%	*Current rates for commercial loans above $100K > 7%*
Loan length (years)	10	
Monthly payment	($518.00)	
Total Loan pmts.	($62,160.00)	
Annual output (kWh's)	19,360	
Design life (years)	30	
kWh's excess	-16,640	Annual metered consumption exceeds on-site generation. However, generation exceeds metered consumption for periods of hours each day
Avoided cost per kWh + CPI	$0.075	
PV rate (kWh)	$0.083	
Current utility rates (kWh)	$0.075	
Avg. Monthly to Utility @ current rate + 3% CPI increases (no PV)	$382.50	
Total paid to Utility over Design Life (no PV)	$137,700.00	
Net benefit over Design Life	$75,540.00	

SECTION III: GROUND SOURCE HEAT PUMP

This project displays all of the complexity expected of any multi-use design with the added challenges associated with combining cooking/dining facilities with grocery retail — eminently sensible from a marketing point of view but potentially burdensome from the standpoint of space conditioning. Operational budgeting is also challenged because of the mechanical conflicts inherent to providing for both kitchen conditions and a perishable inventory. Helena's climate compounds the challenge with brief (relatively), cold winters and more extended, milder seasons.

Circumstances require a system that can provide volumes of conditioned and make-up air at reasonable cost across multiple zones. Conventional systems typically require up-sizing and additional ducting (piping in radiant systems) to meet such challenges.

A system combining geo-exchange with smaller variable air volume (VAV) heat exchangers meets the needs on both the comfort and operations budget fronts.

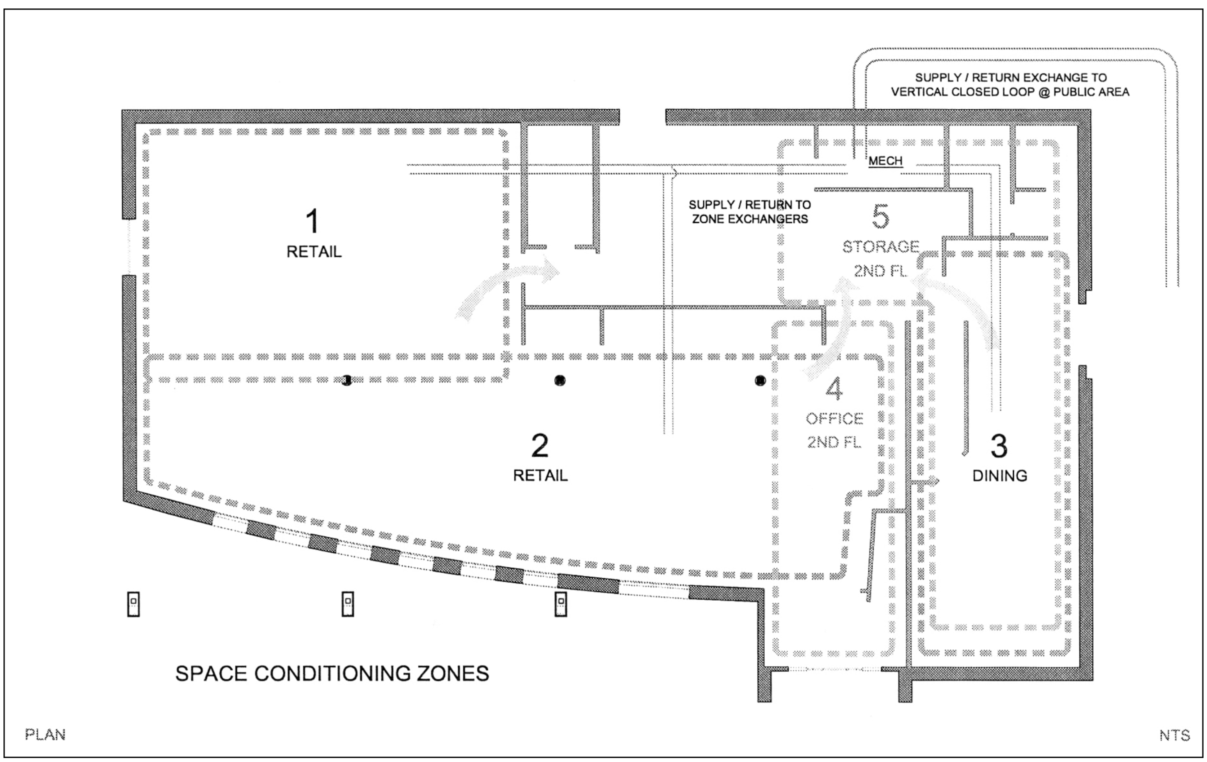
Attachments explaining the principles and operation of GSHP systems are provided. The purpose here is to emphasize the efficiency and adaptability of such systems and to underscore their efficacy in satisfying complex criteria.

GSHP systems perform at efficiencies resulting in heating cost reductions from those of conventional systems ranging from 40% to 70%; and as much as 50% for cooling. Delivery can be accomplished by means of smaller (2'-0" x 2'-0"x 2'-0") VAV exchangers situated within zones with connections to ½" to ¾" supply and return lines. Comfort is significantly improved while the tare burden imposed by extensive ducting or piping is reduced. Moreover, a single system capitalizing on the constant ground temperature serves both needs.

Development of GSHP technology and its market popularity result in current capital costs at, or slightly above, costs for conventional systems. System payback ranges from three to five years

RECOMMENDATIONS:

1. Closed Vertical loop (at easterly Public Area) GSHP w/ zoned exchangers
2. Desuperheater option for hot water
3. Alternative hot water heat harvested from kitchen exhaust



SECTION IV: RAIN HARVEST

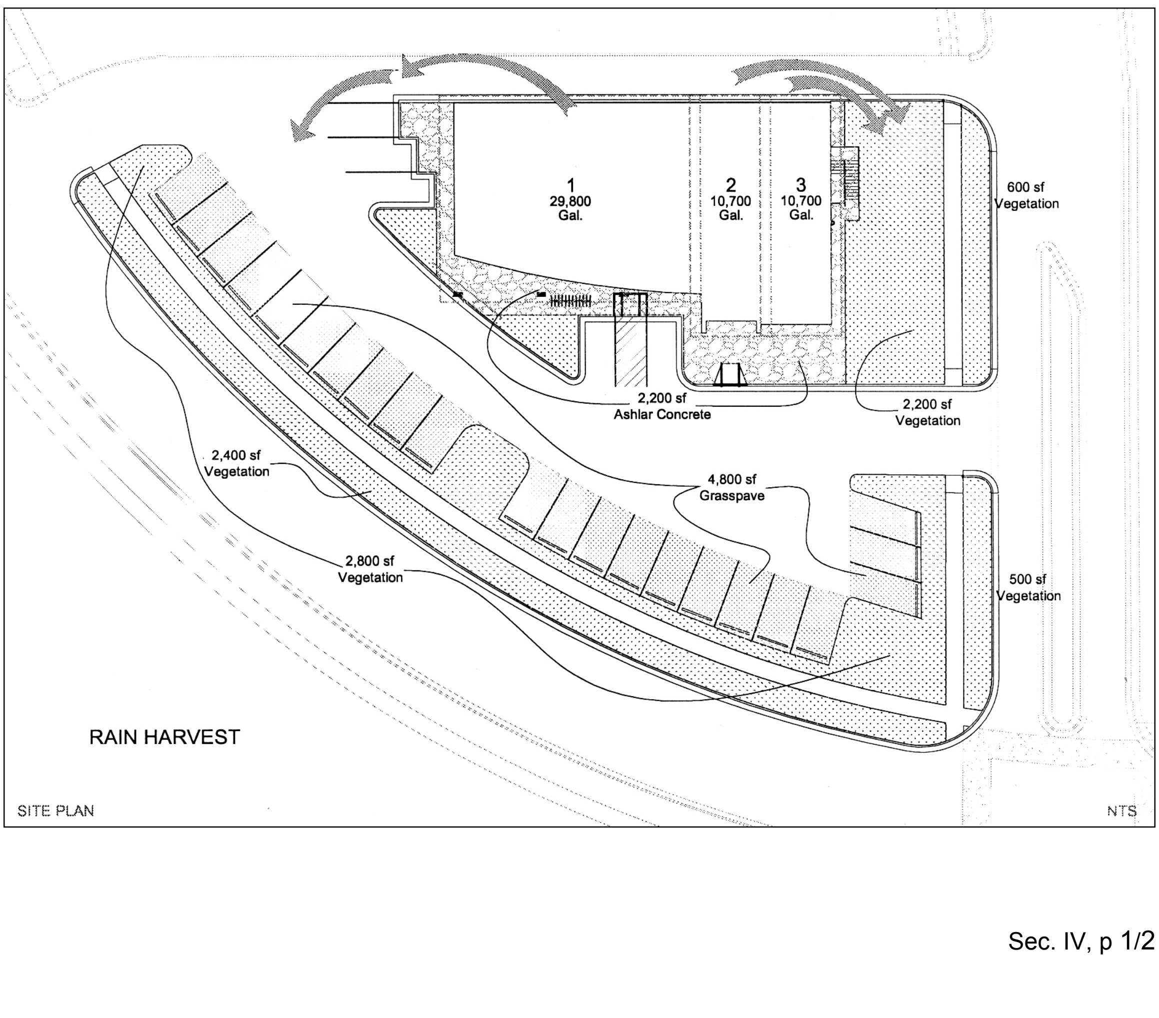
The initial intent was to harvest and capture runoff from the roof, and for good reason — the roof intercepts in excess of 51,000 gallons of water at 11" of annual precipitation. Two reasons argue against the capture (holding in cisterns) side of this equation however: freezing conditions in gutters and the illogic of holding water that is destined for plant irrigation. The better solution lies in directing the intercepted rain directly to vegetation within a larger scheme providing for the sheeting of stormwater across planted areas and the full retention and *treatment* of site runoff.

Typical runoff basins sequester stormwater for the purpose of allowing evaporation (and a minimum of percolation) to dispose of the volume. At the same time, smaller storm events concentrate particulate pollutants at curbed gutters on site for eventual flushing in toxic concentrations (by way of storm sewers and off-site gutters) to regional surface waters during major storm events.

A site scheme incorporating permeable paving, strategically situated, combined with grading leading all runoff to planted areas would resolve both the issue of squandered roof-intercepted water and the failure to treat stormwater.

Specifically, using Invisible Structures' Grasspave² system (or equal) for customer parking areas and grading those areas to planted terrain will dramatically increase the treatment of runoff. That same grading system (micro swales) would serve to distribute roof-intercepted water and smaller storm events. Ashlar (recycled) concrete paving substituted for monolithic concrete patio areas would reduce runoff at one source. The net result would be a landscape populated by healthy vegetation receiving as much as the equivalent of 18" of annual precipitation. At that volume of irrigation, the vegetation would be capable of retaining runoff and sequestering hydrocarbons and heavy metals washed from the remaining impermeable paving.

Grasspave² is engineered to withstand the rigors to which any paving system is subjected including snow removal and fire fighting equipment.



As shown in the line drawing, the permeable customer parking displaces 27% of site paving. The 2,200 square feet of permeable patio reduces site total paving to 10,775 square feet — an area roughly equivalent to the 9,000 square feet planted. The permeable surfaces (and the vegetation they support) will also significantly reduce the Heat Island affect on site and at building perimeter resulting in increased comfort and decreased energy requirements for cooling.

No purpose would be served here by including promotional Acrobat files of Invisible Structures' systems. Their website at http://www.invisiblestructures.com provides exhaustive information on the specifications and benefits of such systems.

RECOMMENDATIONS:

1. 4,800 sf of Grasspave² @ peripheral customer parking graded to planted areas
2. 2,200 sf of Ashlar (recycled) concrete (probably available from Helena City Maintenance at little, or no, cost) in place of monolithic concrete patios
3. Roof runoff directed to planted areas as indicated
4. Stormwater retention basins remain but graded to retain major events at no reduction to sheeting flows

SECTION V: COSTS & MATRIX

Cost estimates are based on recent projects or on past costs adjusted at 3% inflation for the interim. The savings over current mechanical design are included for emphasis only.

MATRIX

	COST ESTIMATES: INITIAL	COST ESTIMATES: INCREMENTAL	DISCIPLINES: ARCHITECTURAL	MECHANICAL	ELECTRICAL	STRUCTURAL	BUILDING OFFICIAL	
PASSIVE GAIN								
South Elevation Fenestration			■			■	MINOR REVIEW	*Some architectural redesign; stuctural review only*
+ 65 sf @ $50		$3,250.00						
- 15 sf @ $50		($750.00)						
+ 8 ea. Precast Sills		$1,200.00						
East Elevation Fenestration			■			■		
- 32 sf @ $50		($1,600.00)						
PHOTOVOLTAIC*								
12.5 Kw Array @ $5,500 / kW	$68,750.00		■		■	■	*Net Metering contract with state; review by Building Official*	*Architectural design; minimal electrical(incl. in purchase); structural for PV frame*
(see Sec. II for analysis)								
GROUND SOURCE HEAT PUMP*								
Say 1 10-ton vertical closed loop	$35,000		■	■	■		*Review & Approval by Building Official*	*Architectural interior; mechanical redesign; electrical downsize*
Savings over current mech. design		($115,000.00)						
Ductwork reduction		($5,000)	■	■				
WATER HARVESTING								
Gutters & Drains		Minor rerouting	■				N.C. MINOR REVIEW	*Some architectural redesign*
4,800 sf Grasspave² @ $2.50		$12,000	■					
4,800 sf asphalt avoided@ $1.25		($6,000)	■					
2,200 sf Ashlar concrete @ $$7.00		$15,400	■					
2,200 sf concrete avoided@ $6.00		($13,200)	■					
Redesign Grading		Minor rerouting	■					

* These systems qualify for tax credits & incentives that significantly affect Year One capital outlay

POTENTIAL COST ABATEMENTS		
Photovoltaic Credit	($24,062.50)	
GSHP Credit	($12,250.00)	
TOTALS	$67,437.50	($109,700.00)
Incremental Costs Less Mechanical Savings		$5,300.00