

A photograph of Mount Everest and surrounding peaks under a clear blue sky. The mountain peaks are covered in snow and partially shrouded in mist. The foreground shows dark, rocky slopes.

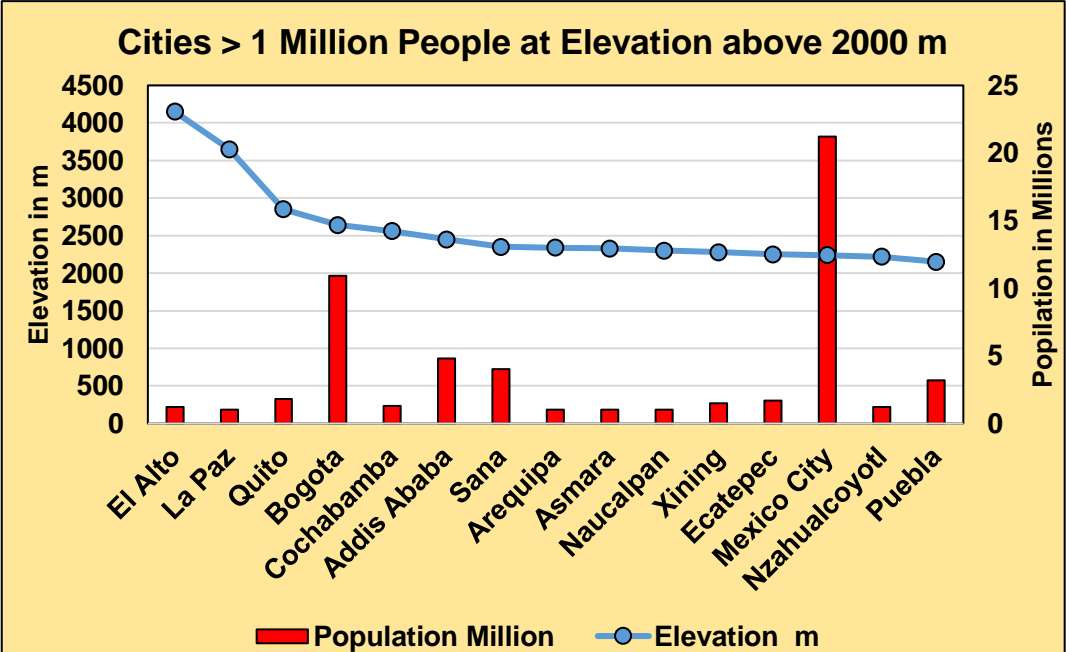
Mt. Everest

Mountain Tourism, Water & Climate Change

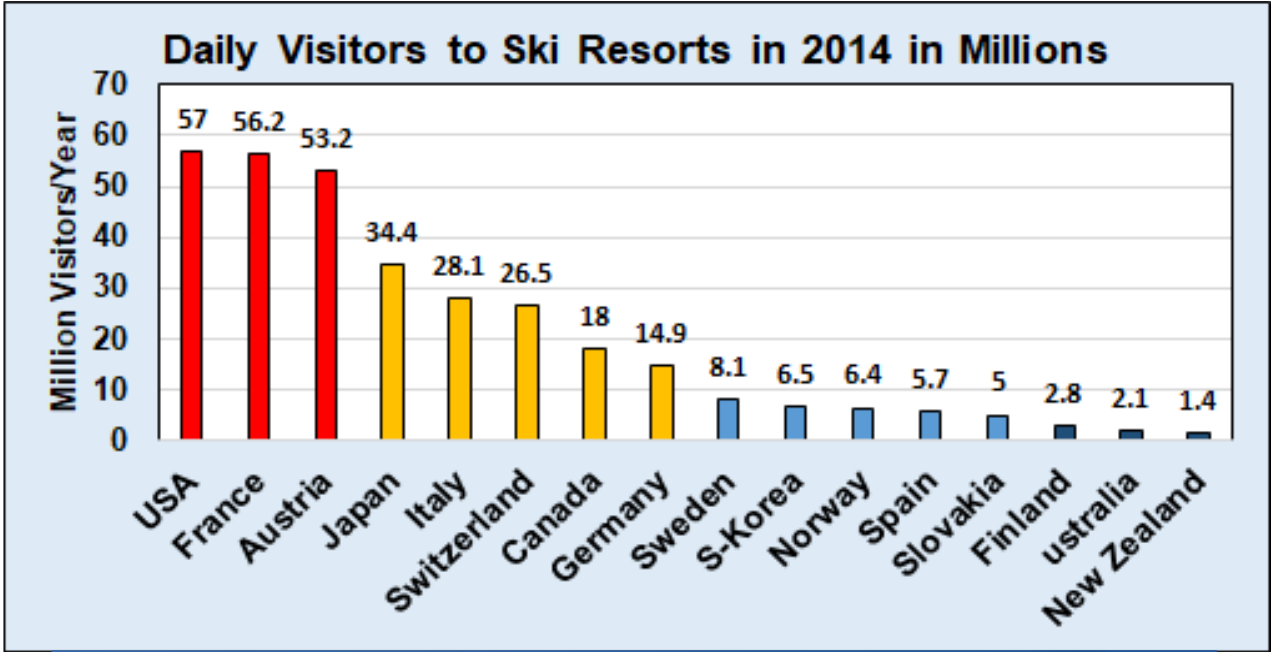
Hans Schreier, UBC, Vancouver, Canada

Urbanization in Mountains

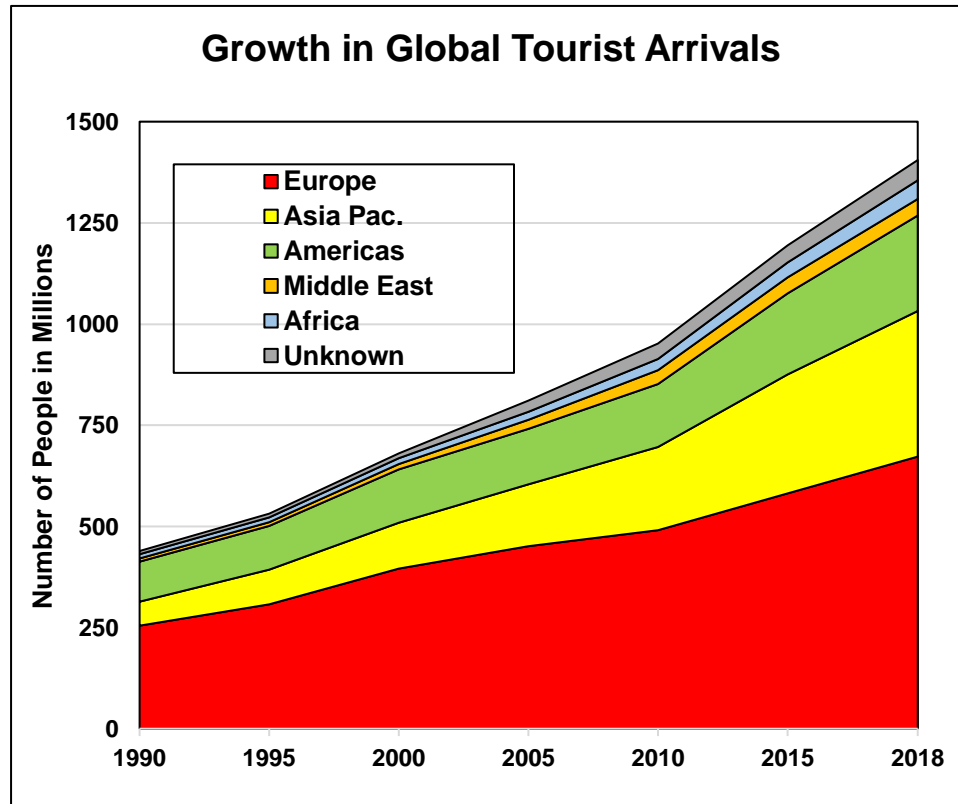
Estimated Permanent Urban Residents in Mountains
400 Million at > 1500m , 140Million at > 2500 m



Estimated Number of Visitors to The Mountains (Accommodations)
330 million Ski Visitors > 1500 m Number of Resorts > 6000



Global Tourism



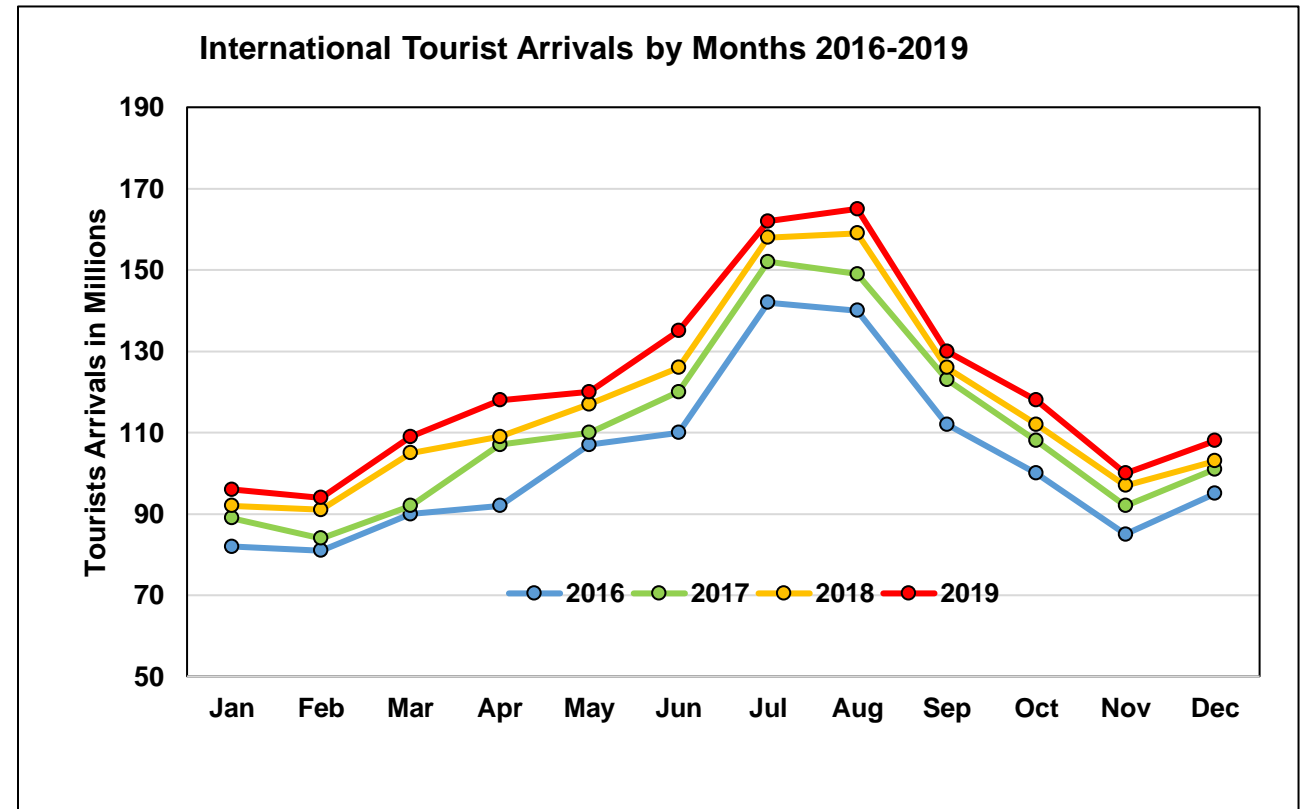
Data Source World Tourism Org. (UNWTO)

2019 = 1.5 Billion Arrivals
(17% of Global Population)

Projected 2020 = ??????

Projected 2030 = 1.8 Billion

Direct Expenditures = \$ 1.5 Trillion



Tourist Numbers and Destinations

Regions	Tourist Destination	Number of Tourists	Tourist Expenditures
	% Global Arrivals	Millions	Billion \$
Europe	51	710	570
Asia Pac.	25	348	435
Americas	15	216	334
Africa	5	67	38
Middle East	4	80	73

Rank	Top Destinations	Tourist Arrivals Millions	Country Population Millions	Tourist Arrivals vs. Local Population %
1	France	89	65	137
2	Spain	83	47	208
3	USA	80	327	25
4	China	63	1430	4
5	Italy	62	61	100
6	Turkey	46	82	56
7	Mexico	41	126	33
8	Germany	39	83	47
9	Thailand	38	69	55
10	UK	36	67	53

In 2018 France & Spain had more Tourist Arrivals than the Number of People Living in their Countries
Italy had the same number of Tourist Arrivals as the Italian Population



Mountain Tourism

15-20% of Global Tourism in Mountains

Global Mountain Tourism

**Employs 50 Million People
5700 Mountain Resorts
400 Million Skier Days
59000 km Skiable Slopes
23000 Skilifts & Gondolas**

Mt. Tourism in European Alps

**Employs 5 Million People
1500 Mountain Resorts
200 Million Skier Days
27000 km Skiable Slopes
9000 Skilifts & Gondolas**



Water & Recreation

Water Use for Golf Courses
Water Use for Snow Making
Reservoirs Water Table Problem

Impacts of Mountain Tourism on Water Resources

Tourist Activities	Impacts on Water Resources
Skiing	High Water Demand for Snow Making & Use of Chemicals, Litter, Sanitation Issues
Hiking	Water Pollution: Litter, Fecal Matter, Pathogens, Nutrients
Golfing	High Water Use, Excess Nutrients, Pesticides, Eutrophication
Mountain Biking	Dust, Sediments, Turbidity, Fecal Issues
Swimming	Nutrients, Pathogens, Chlorine



The Importance of the European Alps for Tourism

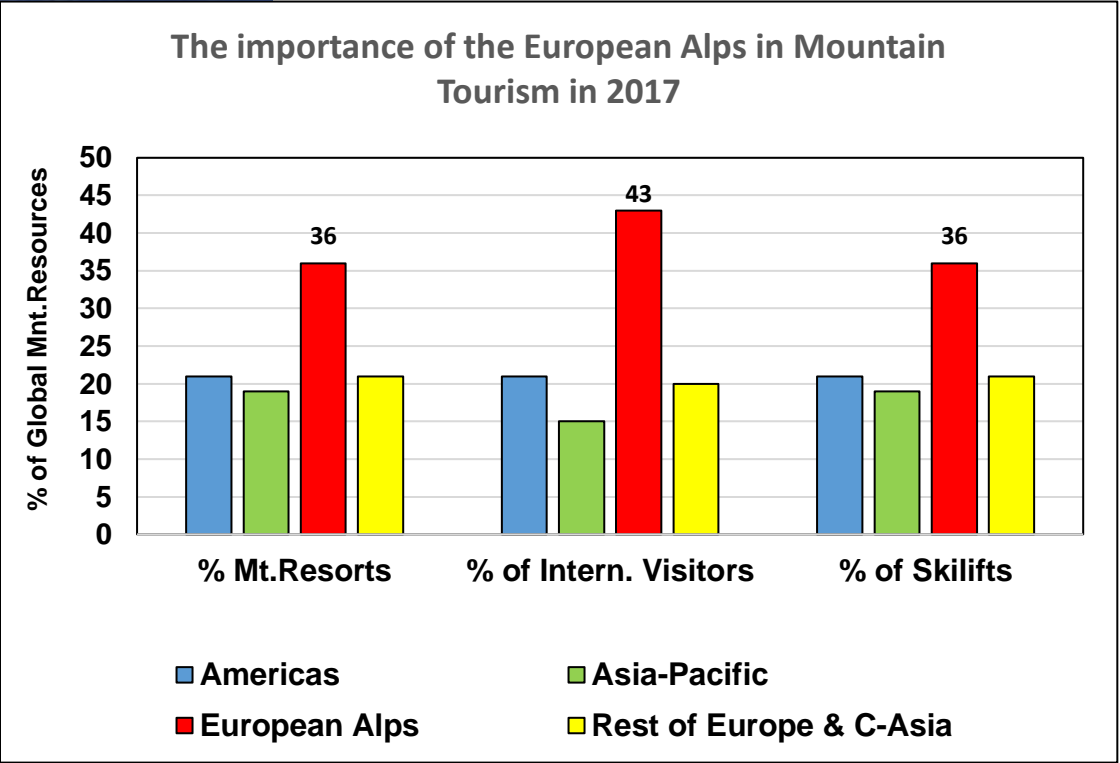


European Alps
60-80 Million Visitors/Year
➤ **660 Major Resorts**

Countries	Number of Skiers	% Population that Skies	Number of Ski Resorts
	Millions	%	Numbers
Germany	14.6	18	498
France	8.5	13	317
Poland	4.9	13	182
Italy	4.9		349
Russia	4.2		354
Austria	2.9	36	253
Switzerland	2.9	37	186
Czech Republic	2.2	22	191
Sweden	1.8	20	228
Finland	1.2	24	76
Norway	1.1	25	213
Total	49	Average = 23%	2847



The Importance of the European Alps in Mountain Tourism



Mountain Landscape Changes by Tourism



Urbanizing Mountains



Snow Farming

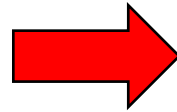


Economic Issues for Mountain Resorts

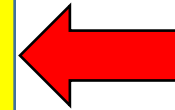
Requirements : 100-120 Days of Secure Skiing (Open at Christmas)
Viable Summer Tourism (Diversity of Activities)
Access, Scenery, Culture

Summer Activities

Hiking & Mt.Climbing
Mt. Biking, Swimming
Paragliding
Sightseeing, Golf



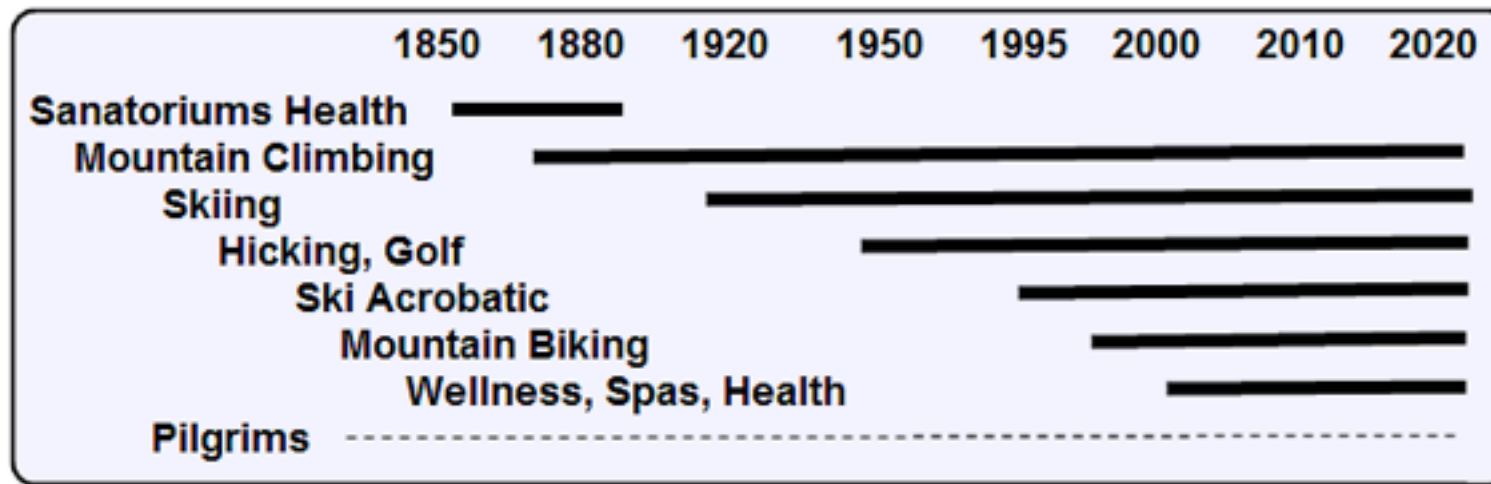
Conferences, Concerts, Festivals
Spas, Wellness, Health
Shopping, Culture, Entertainment



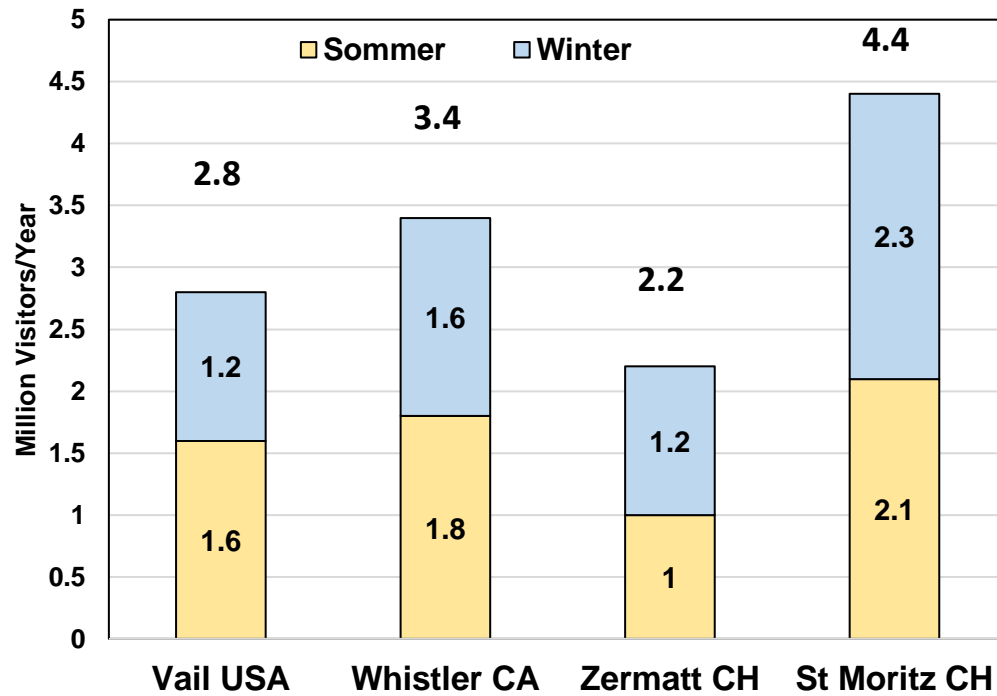
Winter Activities

Skiing (Various Types)
Snowboarding
Ice Skating
Sledding

History of Alpine Tourism



Number of Summer & Winter Visitors/Year in Selected Resorts (in Millions/Year)



To accommodate all these people we are Urbanizing the Mountain Resorts



To be Economically Successful Mountain Resorts need Both Summer & Winter Tourism



Protection for too much Snow



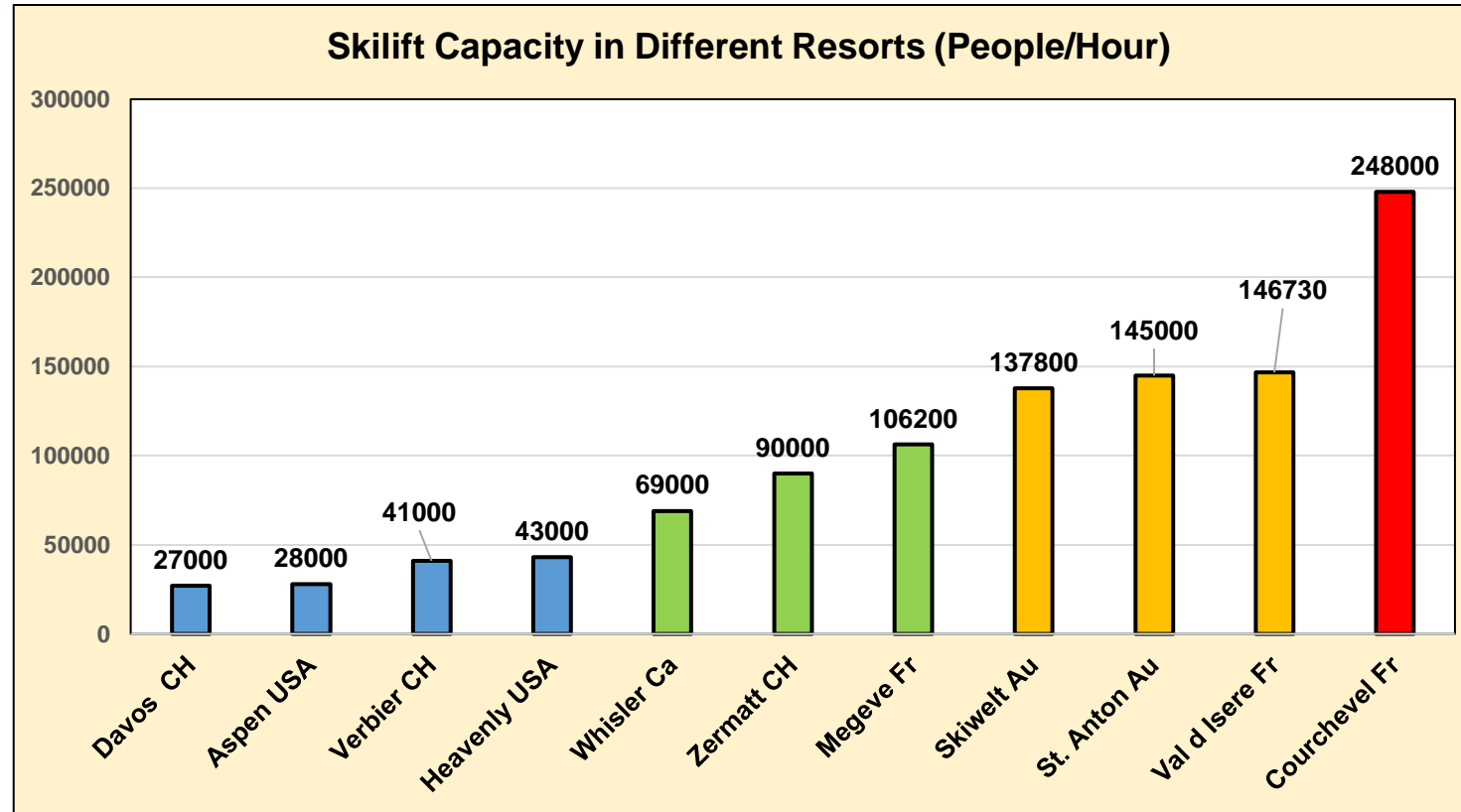
Protection for too little Snow



Mountain Infrastructure for Tourism, in Grindelwald, Switzerland



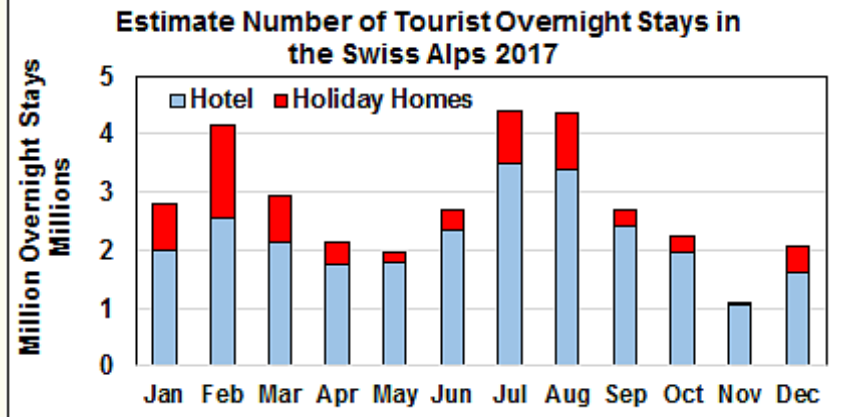
Examples of Ski-Lift Capacity to Move People



Tourism in Switzerland

Number of Ski Resorts : 150
Trails > 2800 m Elevation : 3400km
Mountains > 3000 m " : 208
Number of Lakes : 1500

Total Population : 8.5 Million
Tourist Arrivals : 21 Million (2018)
Tourist Employment : 175000
Total Overnight Stay: 38.8 Millions
(Swiss: 51%, Foreign: 49%)
Hotels: 4400, Hotel Beds: 250000



Total Number of Ski Resorts: 150
20% have 100-650 km of Ski Runs

Resorts	V-Elevation	No. Lifts	No.Runs	Length
Davos	1724 m	55	85	300 km
Verbier	2000 m	88	88	450 km
St Moritz	1373 m	24	89	163 km
Grindelwald	1900 m	66	50	213 km
Zermatt	2279 m	54	147	360 km

Number of Skier Days: 22 million

Trail Network

Hicking	12000 km
Cycling	12000 km
Mt. Biking	8000 km

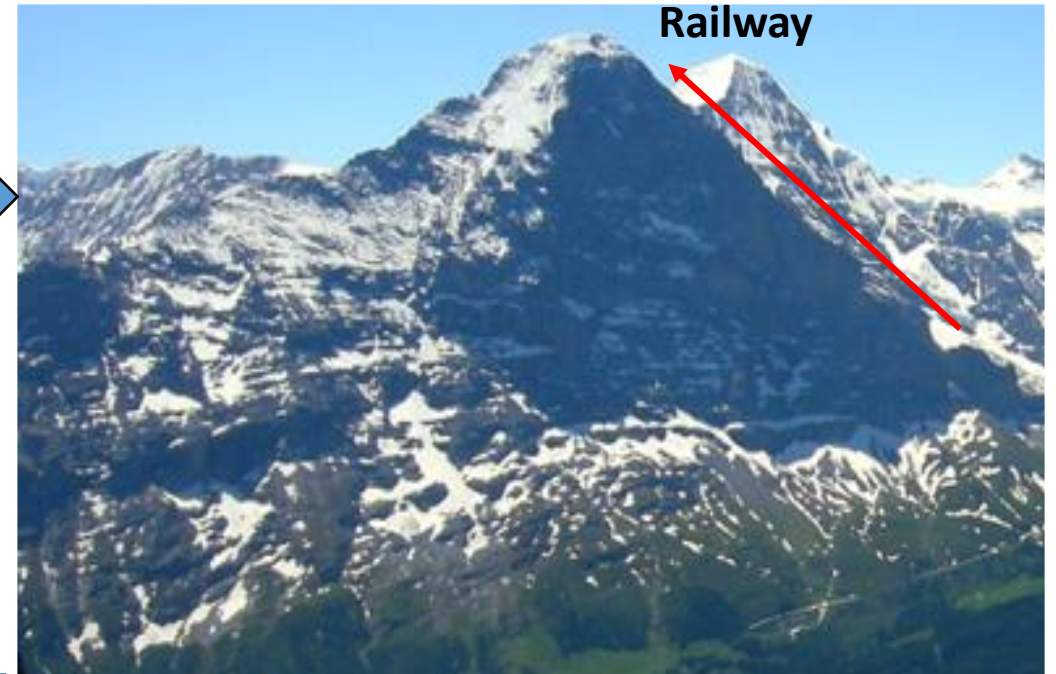
Total Trail Network: 65500 km
Paved Trail Network: 16298 km

Distance Across Canada: 6000 km
Distance Across Russia : 9000 km

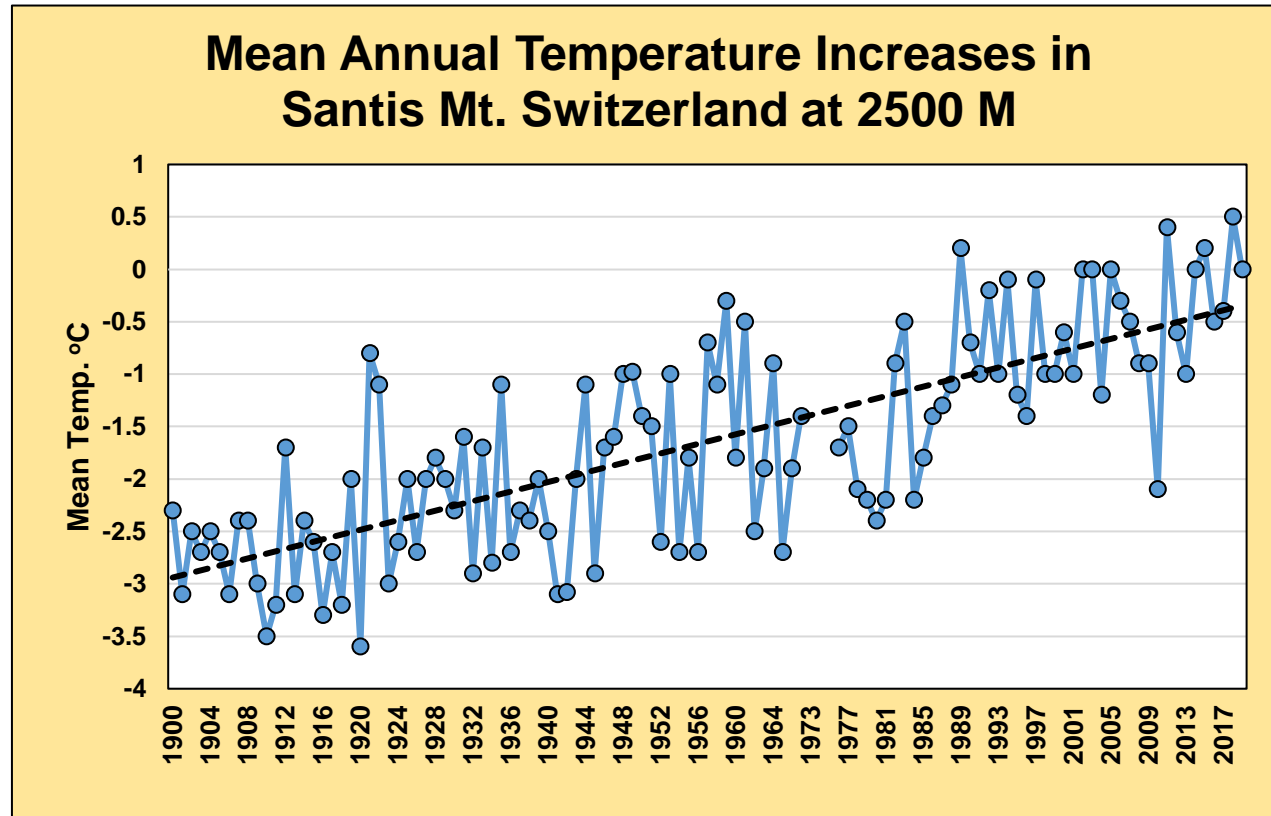


**2018 Number of Rail Passenger
To the Top of the Alps
Jungfraujoch – Aletsch Glacier
3350 m Elevation**

1.07 Million in 2018



Increase = 2.5 ° C over 120 Years

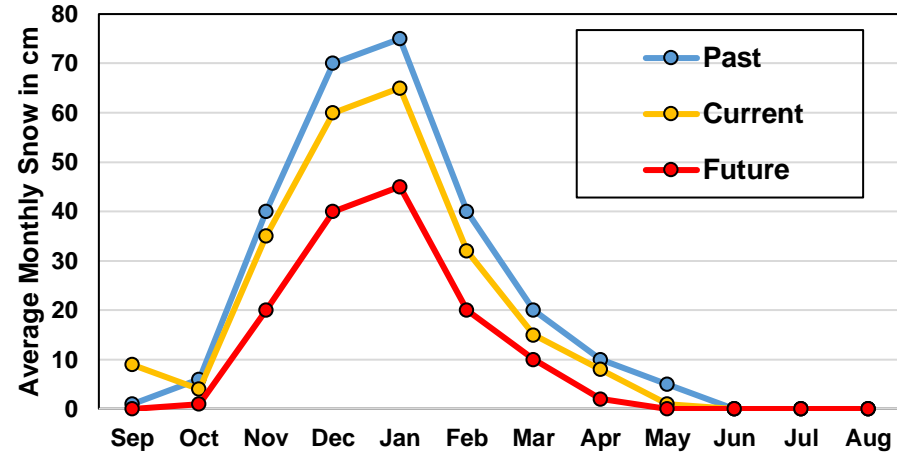


**There are very few
high elevation climate
station with long term
records**

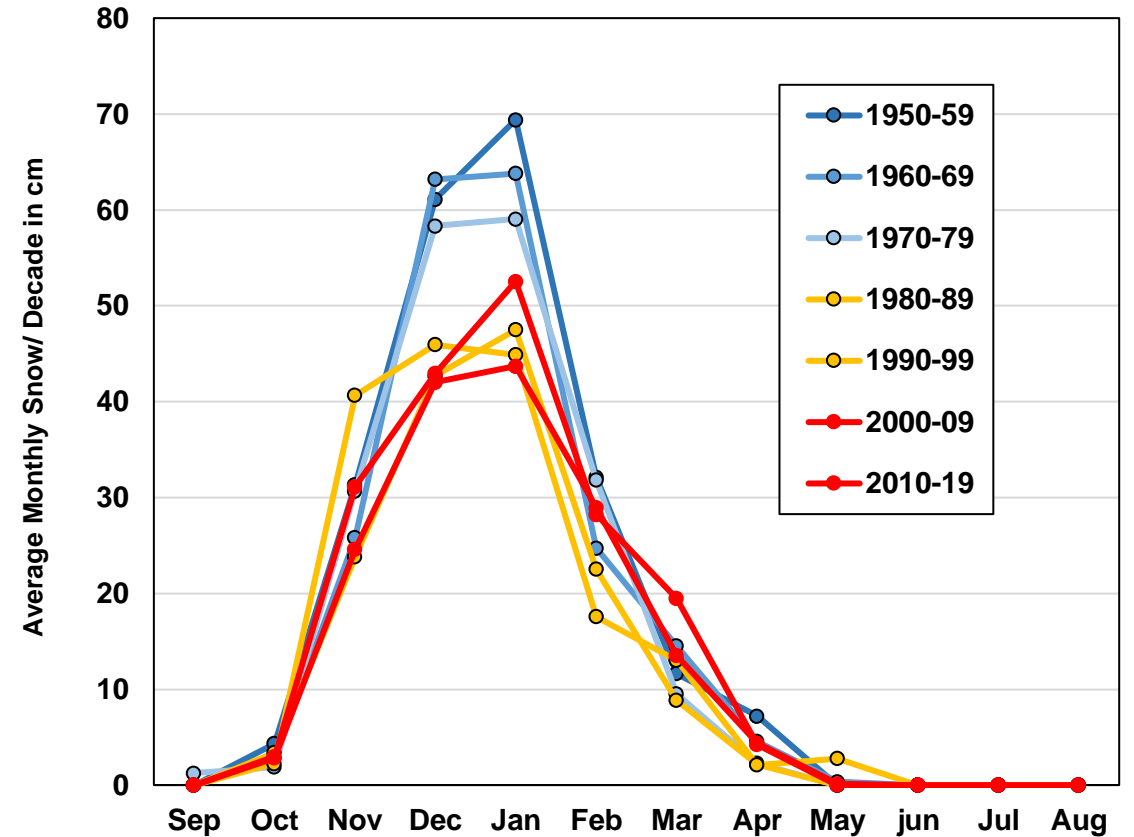
**There is now enough
information available
to show that high
mountains areas are
warming up faster
than many lowland
stations.**

Changes in Snow Accumulation

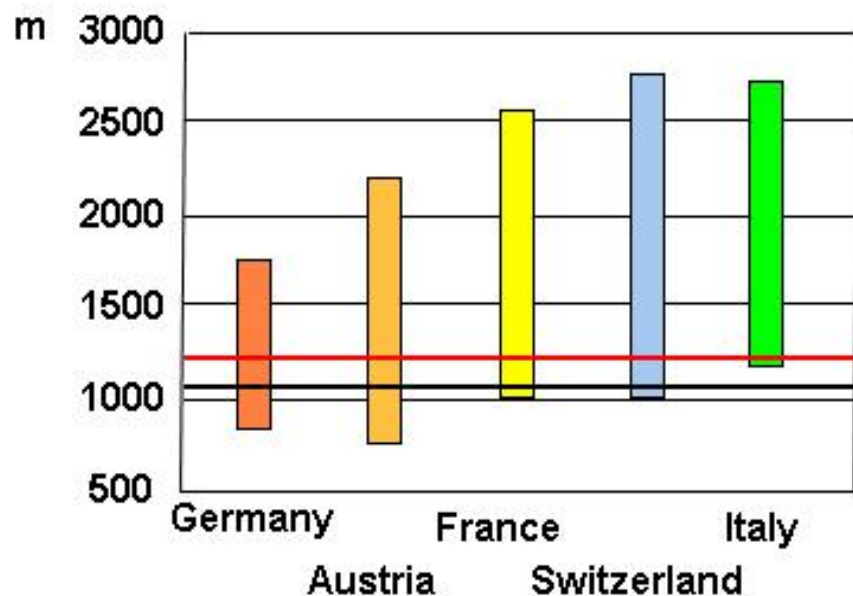
Expected Changes in Snow Accumulation



Average Monthly Snow Accumulation by Decade in Golden, B.C. 1950-2019



Elevation Range of Ski Resorts in the European Alps



**Vulnerability to Temperature
Requires to go Higher & North Facing**

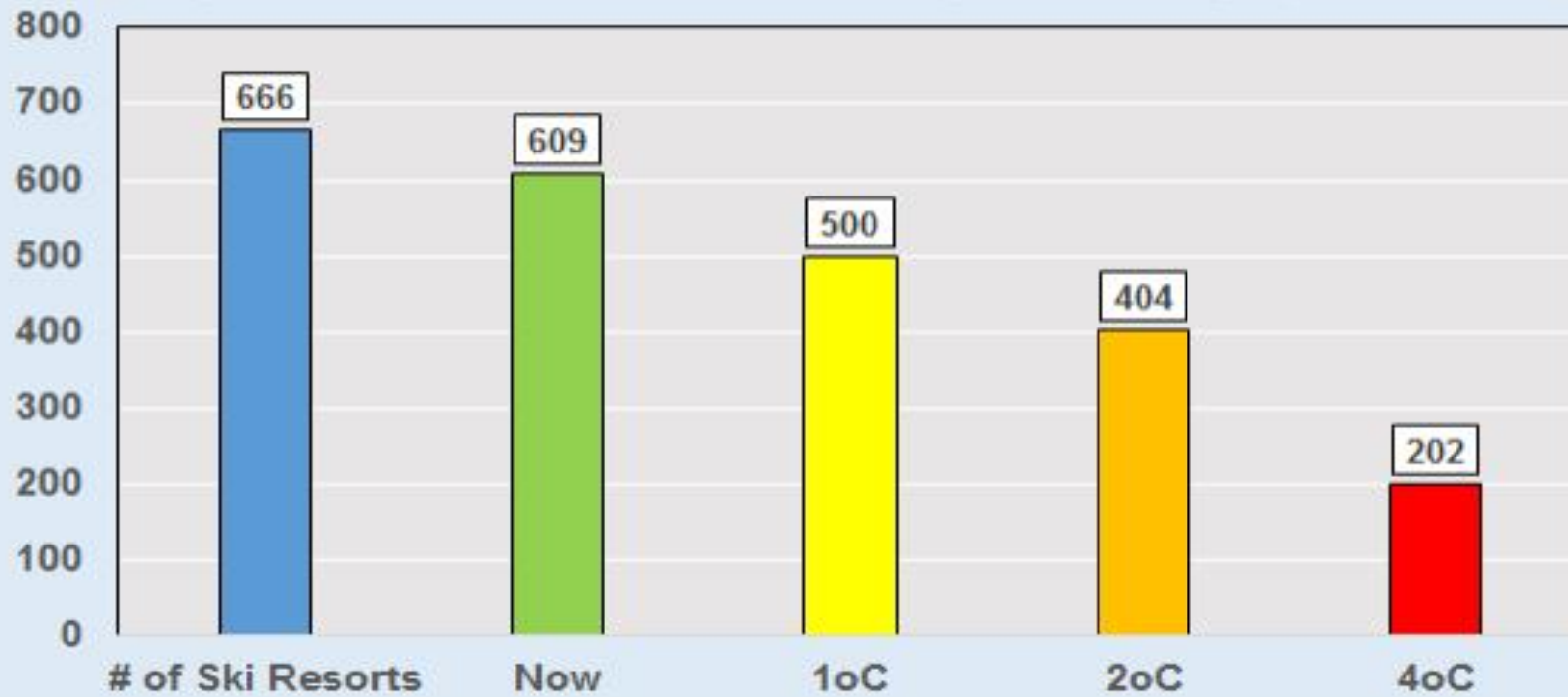
Current Reliable Snow Line = 1050 m
1°C Temperature Increase = 1200 m S
2°C Temperature Increase = 1350 m

Current Reliable Snow Line = 1200 m
1°C Temperature Increase = 1350 m N
2°C Temperature Increase = 1600 m

For every 1°C increase it is estimated
that the permanent Snow Level will
move up in elevation by about by 150 m



Decline in Snow Reliable Ski Resorts in the European Alps with increases in Global Temperatures by 1, 2 & 4°C





Schneesicher? Aber sicher!

Neue Beschneiungsanlage ab Winter 07/08
auf allen Pisten.



Rosswald
Die Sonnenterrasse

Rosswald Bahnen - www.rosswald-bahnen.ch / info@rosswald.ch



Promise of Snow Security



Snow Making

```
graph TD; A[Snow Making] --> B[Water Requirements]; A --> C[Energy Requirements]; B --> D["2000-4000 m³ / ha (30cm)  
~ 0.5 m³ / 1m³ of Snow"]; D --> E["Snow Making Guns  
Cost: $ 6000-30000.-  
Water Use/Gun : ~ 11m³/hr  
Operating time : ~ 120 hrs  
Air Temp. < - 4°C & Humidity  
10-40% Loss (Subl. Evapo.)  
Equal to Irrigates Agric.  
3000 - 4000 m³/ha of Corn"]; C --> F["1050-1350 kWh / ha (30cm)  
3.5-4.5 kWh / 1m³ Snow"]; F --> G["Wide Range of kWh  
Depending on Type of Gun,  
Air Temp. and Humidity  
1 - 14 kWh / 1m³ of Snow  
13-40% of Energy Use in  
Resorts (highly Variable)"];
```

Water Requirements

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~ 0.5 m³ / 1m³ of Snow

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Wide Range of kWh
Depending on Type of Gun,
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13-40% of Energy Use in
Resorts (highly Variable)



Major Ski Resort in the USA

117 Major Ski Resort > 1220 m Elev.

70% Make Snow

Area of Snow Making : 1 -1370 ha

**15 Largest Resorts: 243-1370 ha Snow Making
Use 22 Million m³ of Water**

= Domestic Water Use By 110000 People

Use 2.9-16.3 Million kWh of Electricity

**= Energy Consumption: 290-1630 Households
Equivalent to 13-40% of Resorts Energy Use**

Major Ski Resort in Europe

115 Major Swiss Ski Resorts (35% Make Snow)

254 Major Resorts Austria (70% Make Snow)

349 Major Resorts Italy (~ 80% Make Snow)

325 Major Resorts France (60% Make Snow)



Constructed Water Storage for Snow- Making in the Italian Alps



Snow Fences

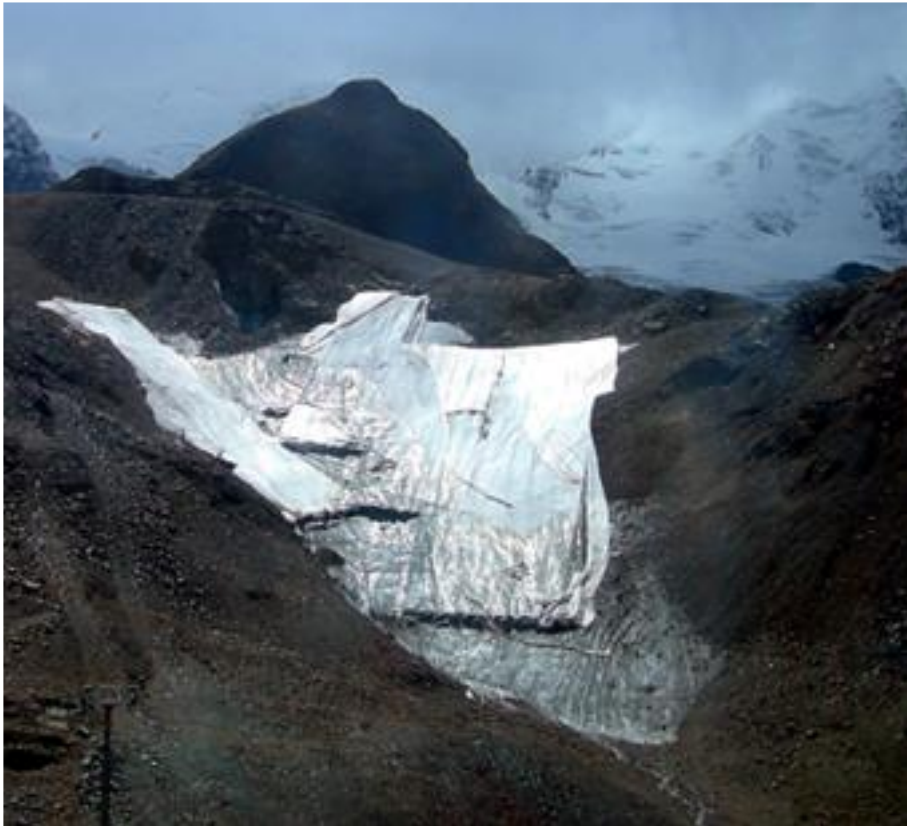


Snow Making



Snow Farming

Make Snow in Winter
Preserve it over Summer
Cover it with Sawdust or Plastic
Provide Snow Base for Christmas



Additives for Snow Making:

Ammonium nitrate,

KCl improves quality, hardens snow

CO₂ or liquid N, Ag (LC50),

Keolinite (enhances crystal formation)

Bacteria *Pseudomonas syringae*

(protein that catalyses ice formation)

Water Sources In Switzerland:

For snow making:

34% Rivers, 30% drinking water,

21% Springs, 15% Lakes

Snow Preservation over Summer

Courchevel France

20000 m³ of Snow

Covered with Insulating Plastic

Davos, Switzerland

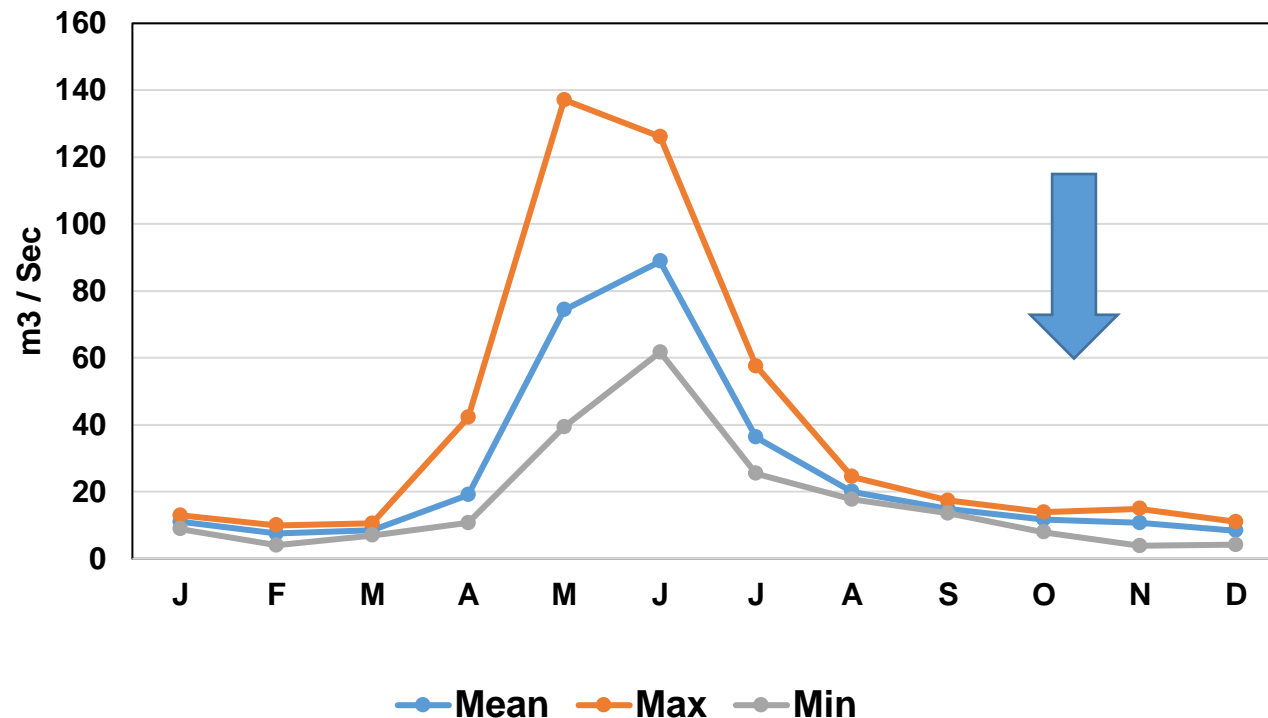
20000 m³ of Snow

Covered with 40 cm Sawdust



Problems when Using River Water for Snow Making

Discharge at Elk Creek near Fernie
Mean Monthly Discharge 1925-2006



**Water Requirement
Timing for Snow Making**

**October- November
When Stream Discharges
are very Low**

**Impacts on
Environmental Services**

Snow Farming Impacts on Water Resources

Impacts

Reasons

Water Demand

**Snow Making & Storage
Hydropower**

Pollution (NPS)

**Adatives to Snow Making
Soil Erosion -Turbidity**

Green House Gases

**Increased Energy Use
For Snow Making & Pumping**

Hydrological Cycle

**River Water Extraction
during Low Flow Period
Impacts Environmental Services**



Protection Infrastructures



Brienzen, Switzerland Major Debris Flow in 2009



2003

Before



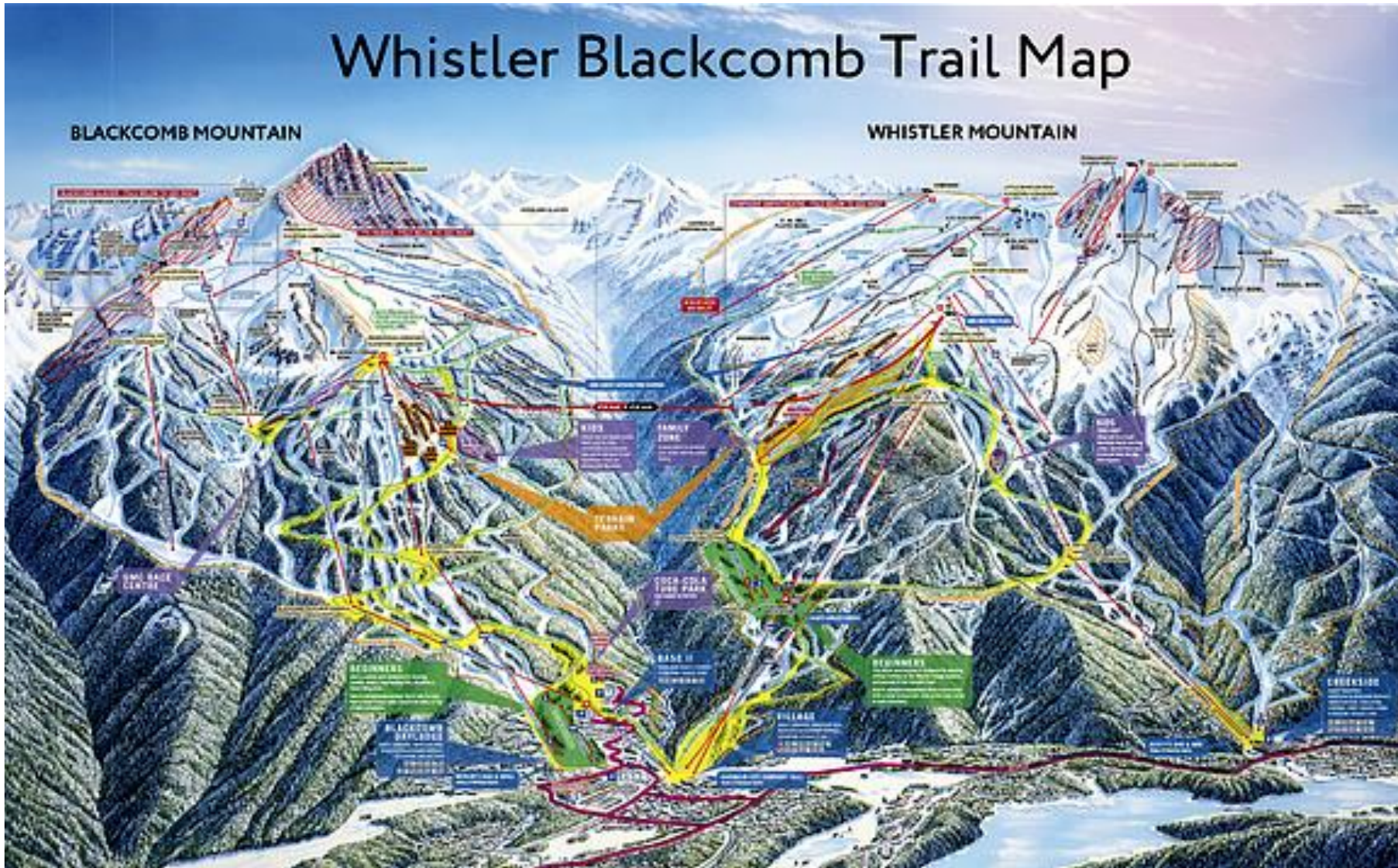
2009

After

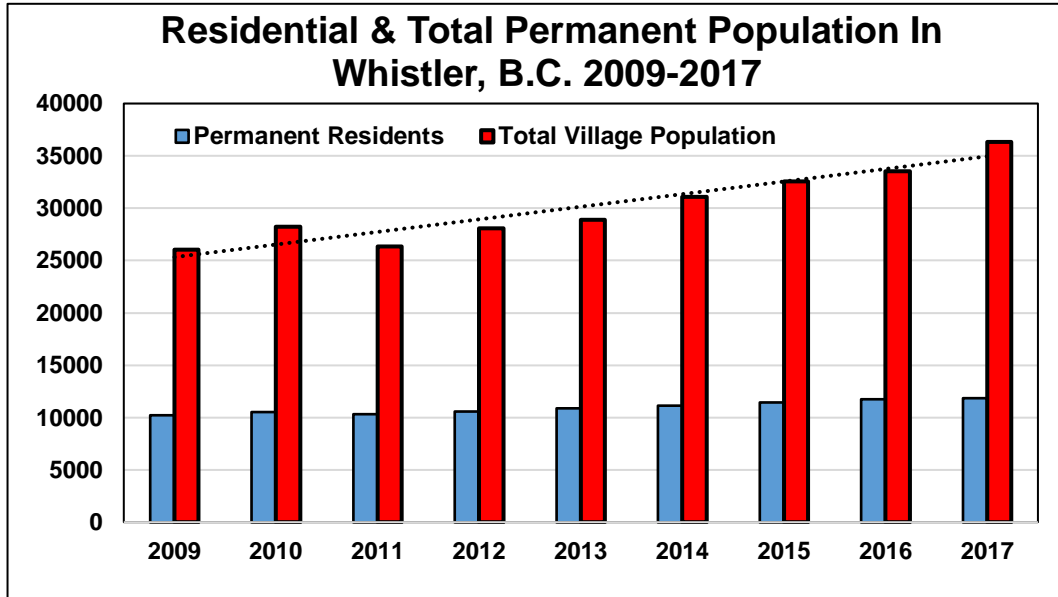




Case Study: Whistler Resorts, B.C. Canada







**In 2018
35000
Residents**



**3.5 Million
Visitors**

**Ratio
1:100**

Whistler at a Glance:

**150 Hotels (30000 Beds/Days)
Other Accommodations 10000 Beds
200 Restaurants & Bars
200 Shops**

**37 Ski Lifts & Gondolas
Lift Capacity 70000 People/ Hour**

**200 Ski Runs (50 km)
1600 m Vertical Drop
36 Snow Making Guns**

**4 Golf Courses (23500 Golf Rounds)
250 km of Mt. Biking Trails**

**Winter Visitors 45%
Summer Visitors 55%**

Green Initiatives are Essential to Attract Tourists in Many Mountain Resorts

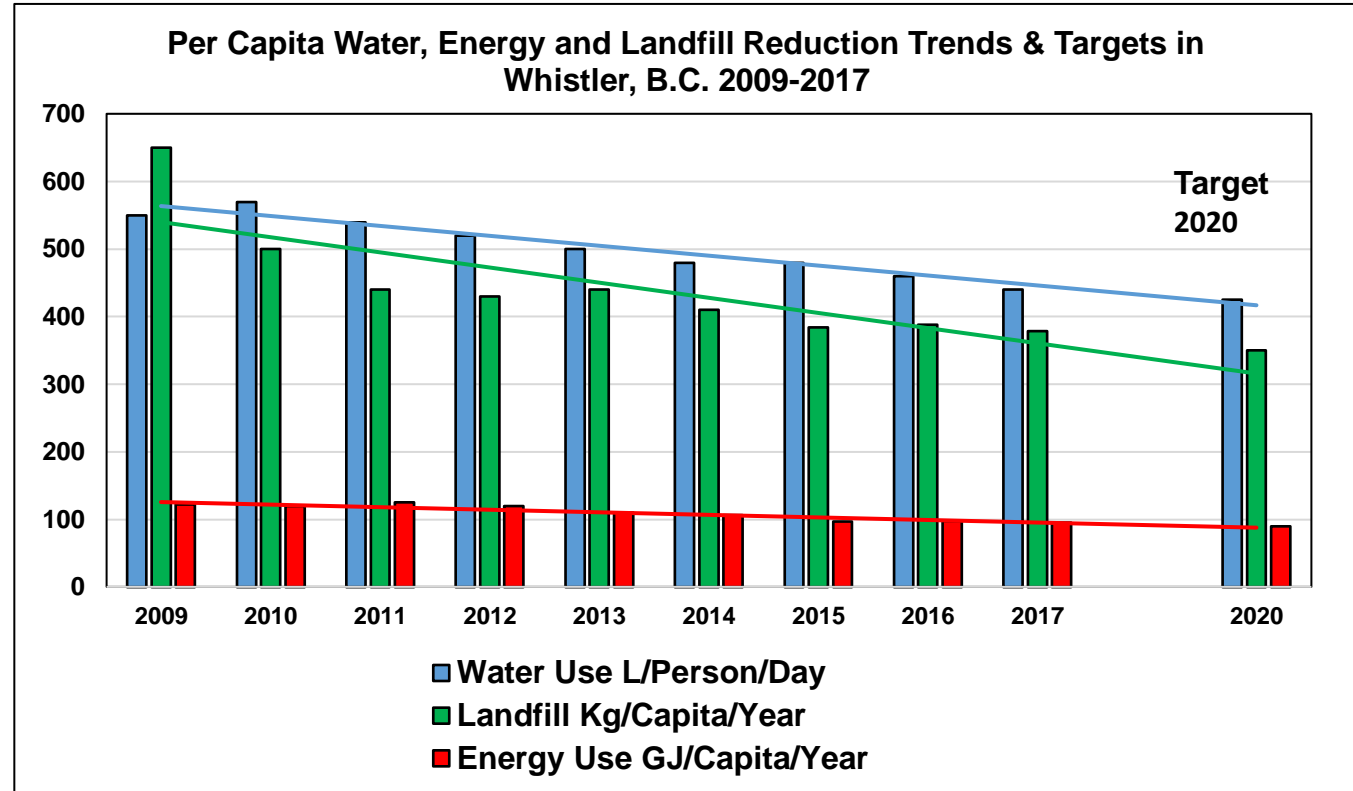
Whistler in Canada Hosted the 2010 Winter Olympics

Before the Olympics Whistler Set Environmental Targets to be Reached 2020 :

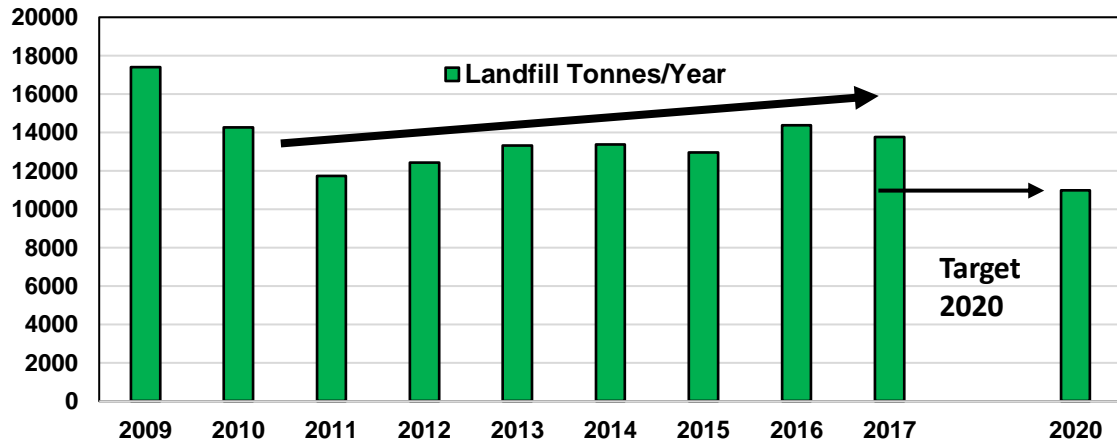
Reduction in Water & Energy Consumption

Reduction in Landfill Deposition

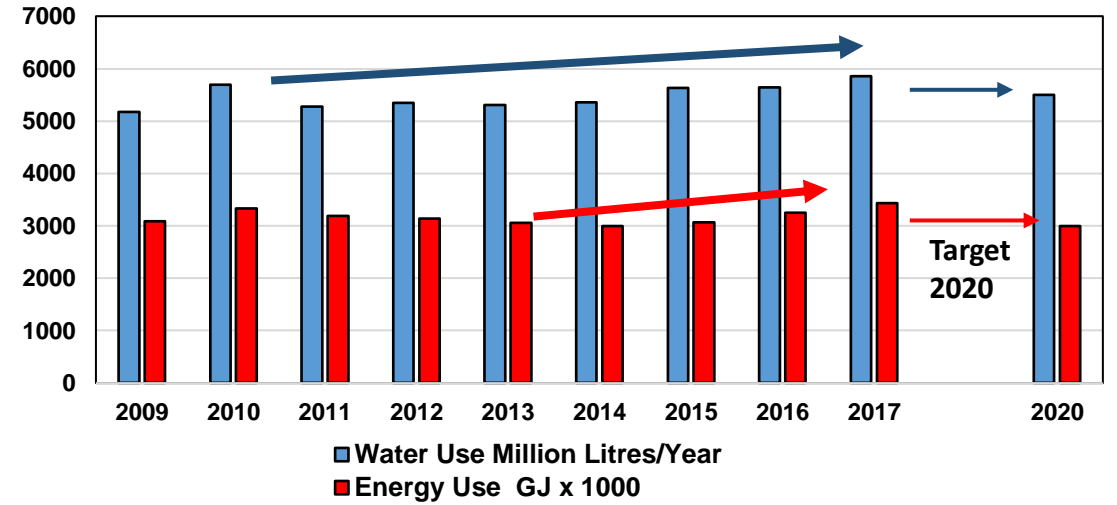
Reductions in Total CO₂ (equ.) Emissions



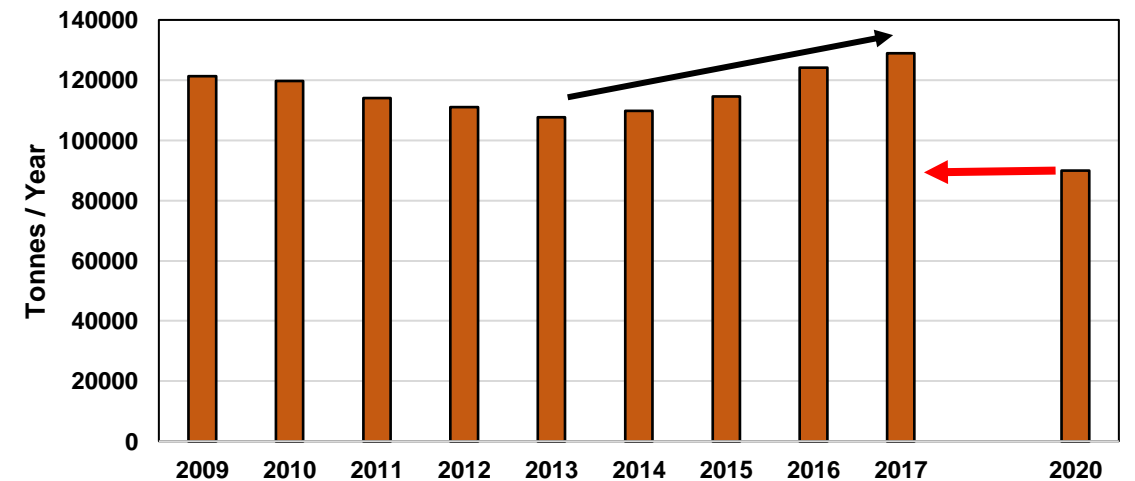
Total Landfill Production Trends vs. Target in Whistler, B.C.



Total Water & Energy Use and Targets in Whistler, B.C.



Total CO2 equ. Emissions in Whistler, B.C.



Glacier in the Headwaters of Whistler



New Experiment in Whistler

**4 Snow Guns to make
Snow on Glacier in Winter**

**Trying to Compensate for
Glacial Melt in the Summer**

Question: Economic Viability

Summer Tourism in Mountains

Mountain Biking in the Columbia Basin, B.C.

Mountain Resorts	Number of Biking Trails	Length of Biking Trails
Kimberley/Cranbrook	148	253 km
Fernie	241	151 km
Golden	122	167 km
Revelstoke	111	123 km
Nelson	164	133 km
Rossland	141	145 km



Photo: Luc Anderson



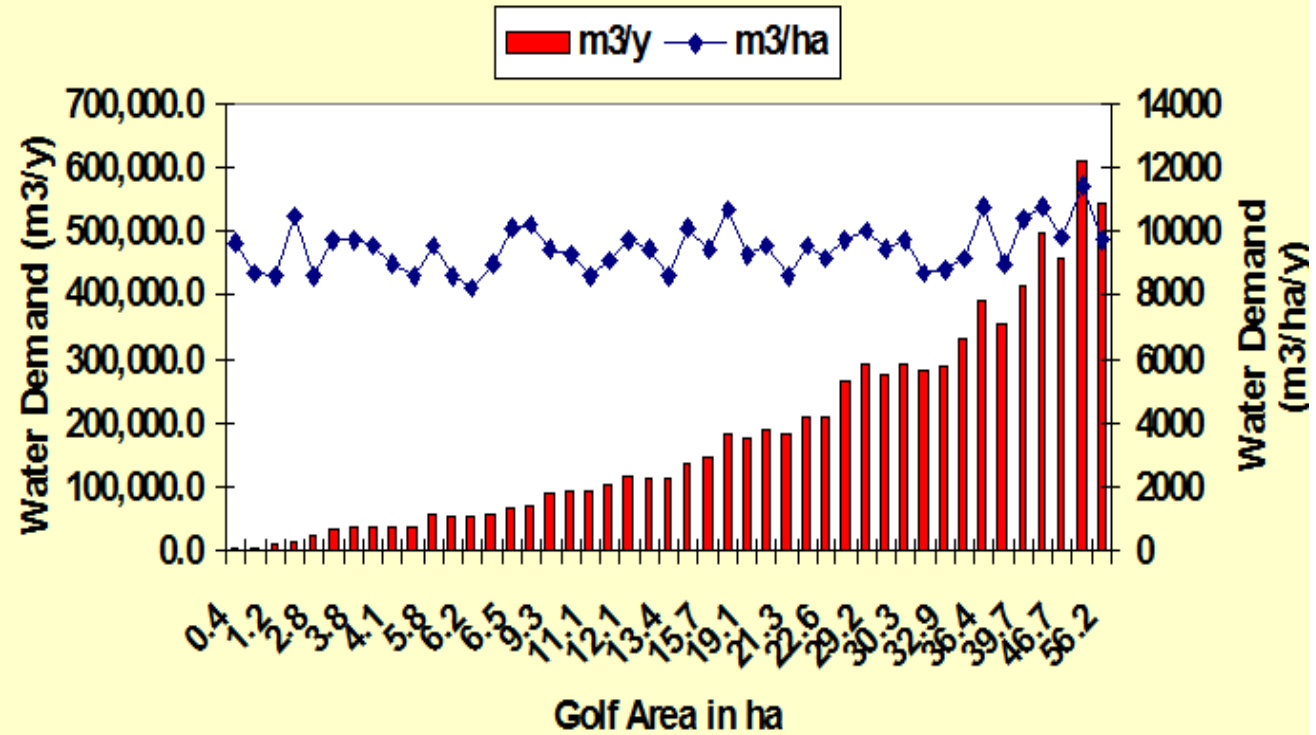
Okanagan Basin

of Golf Courses
in 2006 : 45

Total area:
1048 ha

Total Annual Irrigation
Water Demand:
10,174,293 m³

Golf Course Irrigation Water Demand by Size of Golf Course

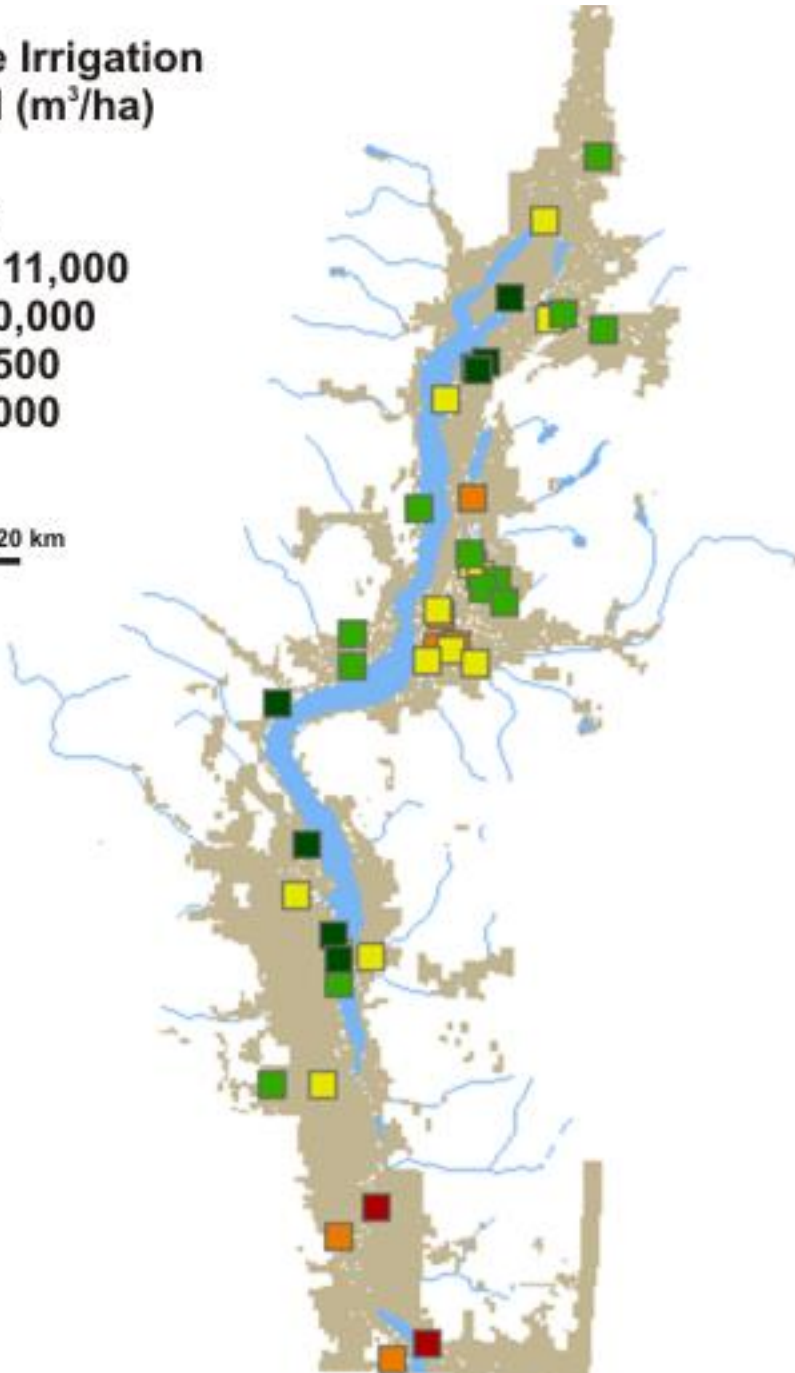
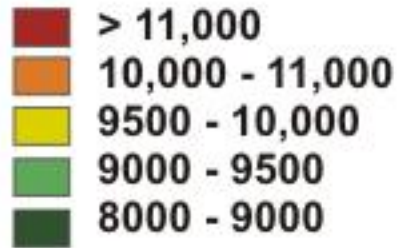


Average Irrigation Water
Demand for Golf Courses:
9708 m³/ha/season

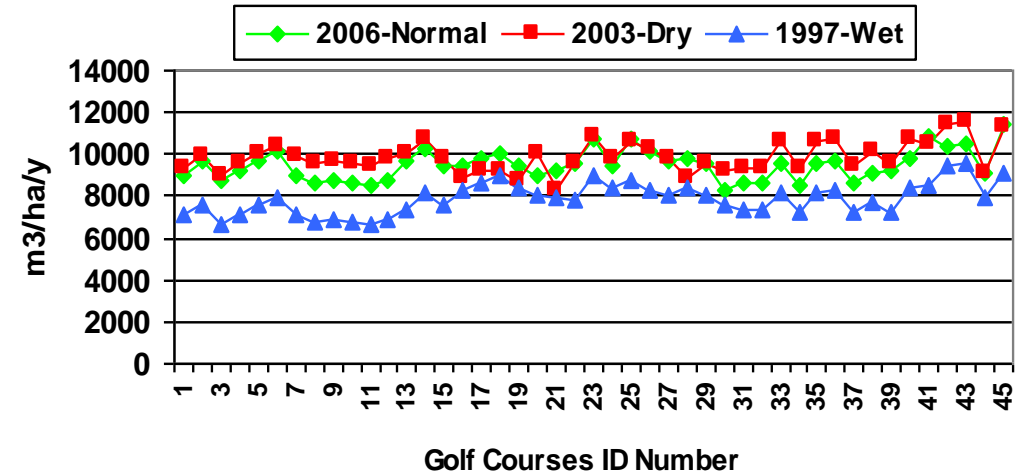
Average/Course:
179550 m³/year



2006 Golf Course Irrigation Water Demand (m³/ha)



Wet v. Dry vs. Normal Year Irrigation Water Demand for Golf Courses (m³/ha/y)



Average Golf Course Water Use In the Okanagan Watershed

9700 m³/ha (20-40% over irrigated)-
Difference: Wet & Dry Years: 29%-38%

Average Water Use for Crops: 6100 m³/ha



Mount Blanc

**Highest Peak
in the Alps**

Elevation 4810 m

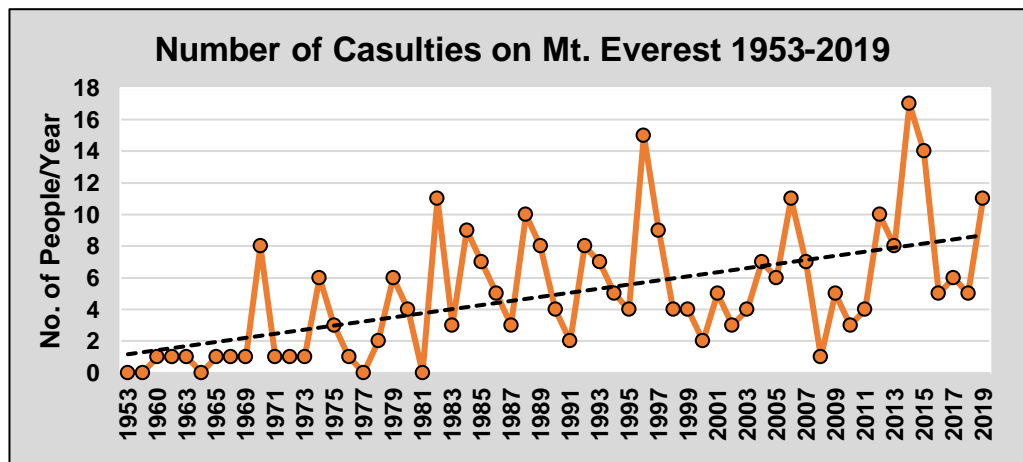
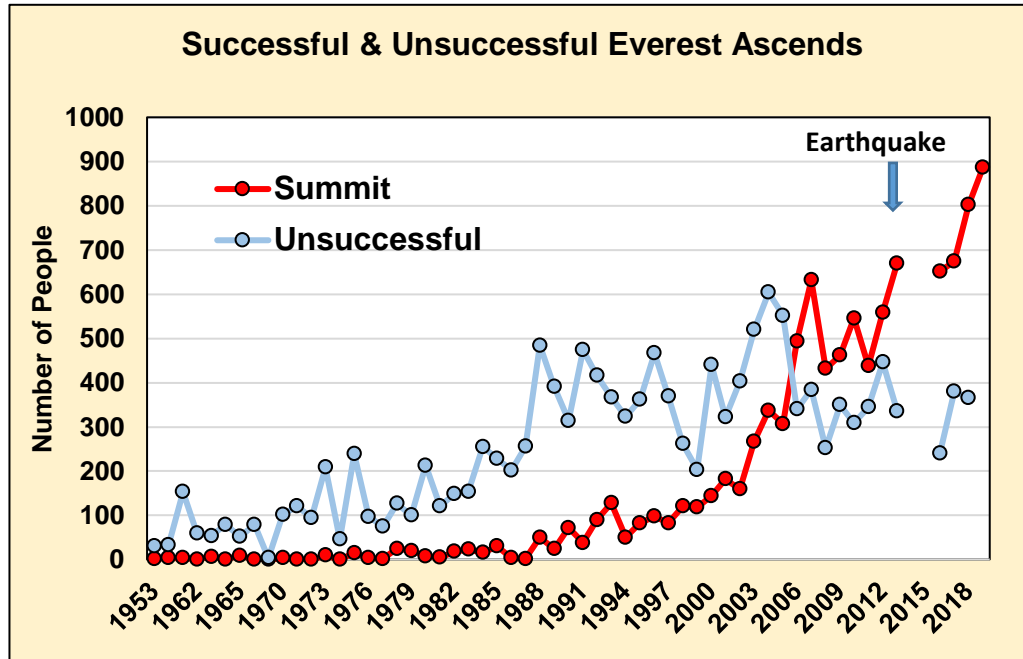


**Around 30000 people attempt the Peak/Year
Average 400/day
Around 60% get sick & fail to reach the peak
Around 100 rescues/year by Helicopter
500 kg/Week of Trash removed by Helicopter**

**1-16 death/year
More Dangerous Climb due to Climate
Warming Glacial Melt & Permafrost**

**In 2018 Set Limits of 214/Day
because of Overcrowding**

History of Mt. Everest



First Successful Summit: 1953 Hillary/Tensing
Successful Climbs 1953-2019 10050 People
Attempted Climbs 1953-2019 23917 People
Casualties 1953-2019 291 People





North Face

Thank you!